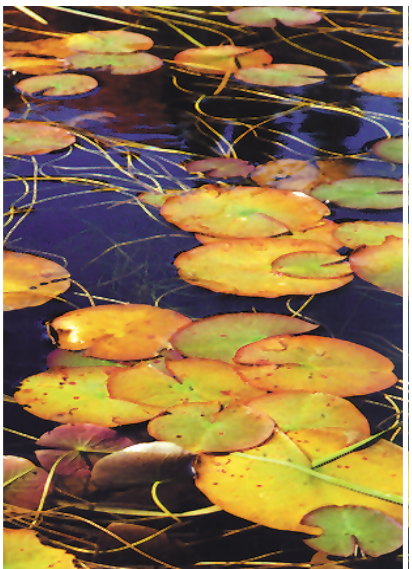

REVISION NO. 3

Periphyton-Based Stormwater Treatment Area (PSTA) Research and Demonstration Project

PSTA Research Plan

Prepared for

South Florida
Water Management District

Prepared by

CH2MHILL

April 2001

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May 2, 2001

148010.P2.02.CH

Ms. Lori Wenkert
South Florida Water Management District
3301Gun Club Road
West Palm Beach, FL 33416

Subject: PSTA Research Plan (Revision No. 3) for the PSTA Research and Demonstration Project (C-E8624)

Dear Lori:

The *PSTA Research Plan* was originally issued in August 1998, and has been updated and reissued twice since then to incorporate information and recommendations resulting from the project. The enclosed document (Revision No. 3) has been updated to describe Phase 2 activities at the three project locations (ENR Test Cells, Porta-PSTA mesocosms, and the Field-Scale Cells). We are enclosing six (6) copies of the document along with an additional camera-ready copy that the District can use to make internal copies should the need arise. The report files are being converted to .pdf format and will be forwarded to you in the near future.

Copies of the document are being sent to the four members of the PSTA Scientific Review Panel: Ramesh Reddy, Bob Wetzel, Jan Stevenson and Jan Vymazal. In addition, we are forwarding copies to Frank Nearhoof and Taufiqal Aziz at the Florida Department of Environmental Protection, Nick Aumen at the National Park Service, Ron Jones at FIU (c/o Evelyn Gaiser), Bob Kadlec and Bill Walker. These additional copies will be shipped later this week.

As always, should any questions arise regarding the enclosures, please feel free to call.

Sincerely,

CH2M HILL

for Steven W. Gong
Project Manager

enclosures
DFB/011200017/SET2002.DOC
c: Jana Newman/SFWMD
Bob Knight/WSI
Jim Bays/CH2M HILL
Ellen Patterson/CH2M HILL

Foreword

This *PSTA Research Plan* is the basis for this evaluation of the PSTA concept. This Plan was originally issued in August 1998 (CH2M HILL, 1998a), and has been updated and reissued twice since then (CH2M HILL, 1998b and 1999) to incorporate information and recommendations resulting from the project. This version of the *PSTA Research Plan* has been prepared with the primary objective of describing the final design and planned operation of the field-scale mesocosms during Phase 2 of this research and demonstration project.

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Acronymns and Abbreviations

AFDW	Ash-free dry weight
BMP	Best Management Practices
EAA	Everglades Agricultural Act
ECP	Everglades Construction Project
EFA	Everglades Forever Act of 1994
ENR	Everglades Nutrient Removal
EPA	Environmental Protection Agency
FDEP	Florida Department of Environmental Protection
GPP	gross primary productivity
µg/L	micrograms per liter
m/y	month per year
NPP	net primary production
O&M	operations and maintenance
PSTA	periphyton-based stormwater treatment area
RP	review panel
STA	stormwater treatment areas
TP	total phosphorus
USACOE	United States Army Corps of Engineers
WCA	Water Conservation Areas

SECTION 1

Introduction

1.1 Research Objectives

The Everglades Forever Act of 1994 (EFA) requires that waters released from the Everglades Agricultural Area (EAA), south to the Water Conservation Areas (WCAs), meet a total phosphorus (TP) threshold discharge limit that protects the natural ecosystems of the remaining Everglades. To further this objective, the EFA codified elements of the state's Everglades Construction Project (ECP) into two phases. Under Phase 1 of the ECP, the primary focus is placed on testing, design, and construction of more than 40,000 acres of macrophyte-based stormwater treatment areas (STAs). These wetland marshes are designed to reduce concentrations of TP in waters released to the WCAs to comply with an interim standard of 50 parts per billion (ppb).

The EFA recognized that this interim TP standard may not be low enough to prevent alteration of the aquatic and wetland ecosystems downstream in the remaining Everglades; ongoing research and an anticipated formal rulemaking process will seek to define what the ultimate TP standard will be. Some primary research in the Everglades has suggested that the ultimate protective TP threshold could be as low as 10 ppb (McCormick and O'Dell, 1996; McCormick et al., 1996; McCormick et al., 1998). To achieve a reduction from approximately 50 ppb to levels as low as 10 ppb TP, the EFA anticipated that advanced treatment technologies will be necessary during Phase 1I of the ECP to work in concert with Agricultural Best Management Practices (BMPs) and STAs to achieve the desired level of treatment. Exhibit 1-1 displays the overall project schedule for implementation of the EFA, and illustrates the importance of advanced treatment technology demonstration studies to the ECP.

The South Florida Water Management District (District), Florida Department of Environmental Protection (FDEP), U.S. Environmental Protection Agency (EPA), National Park Service, Everglades Agricultural Area Environmental Protection District, and the U.S. Army Corps of Engineers (USACOE) are conducting and/or supervising research and demonstration projects directed at evaluating a number of candidate advanced treatment technologies. The EFA specifies that candidate advanced treatment technologies be evaluated based on their technical, economic, and environmental feasibility. The objective of these projects is to identify preferred technologies that should be designed and implemented full-scale to supplement STA treatment performance during Phase 2 of the ECP. Exhibit 1-2 illustrates the original proposed timeline for completion of advanced treatment technology research.

Periphyton-based STAs (PSTAs) have been recommended as a concept for phosphorus (P) reduction based on the observation that calcareous blue-green periphyton-dominated plant communities are typical of low P regions of the Everglades (Doren and Jones, 1996; Browder et al., 1994). Periphyton-dominated algal systems have been proposed for wastewater

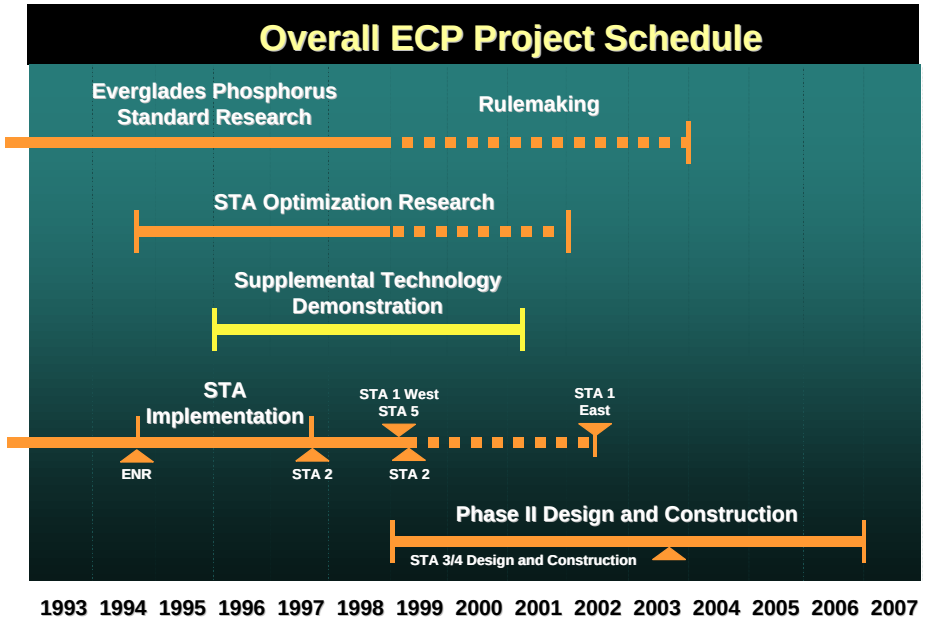


EXHIBIT 1-1
Approximate Schedule for Implementation of the Everglades Forever Act Showing Position of Advanced Treatment Technology Demonstration in the Overall Schedule (District, 1997)

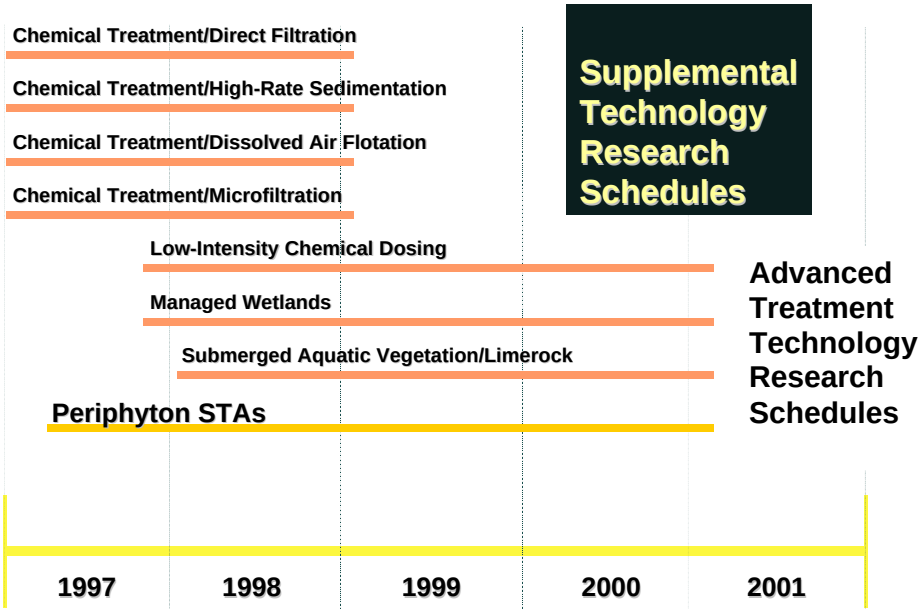


EXHIBIT 1-2
Schedule for Evaluation of Advanced Treatment Technologies (District, 1997)

nutrient control (Vymazal, 1988; Adey et al., 1993; and Drenner et al., 1997); however, systems proposed to-date require harvesting and disposal of the periphyton directly or indirectly. Additional research and demonstration must be conducted to move the PSTA proposal from concept to technical reality.

Examination of the basis for the proposed use of PSTAs for P removal has indicated that insufficient data existed prior to this project to compare their technical and economic feasibility to other identified advanced treatment technologies (Kadlec, 1996a, 1996b; Kadlec and Walker, 1996). However, considerable data do exist regarding natural Everglades periphyton populations and their environmental determinants. For these reasons it is necessary to evaluate existing data and to conduct additional research and pilot-testing of the PSTA concept to meet the EFA's criteria for alternative advanced treatment technology evaluation.

Prior to initiation of the District's PSTA project in July 1998, detailed research to evaluate PSTA feasibility had not been performed. With this limitation in mind, the PSTA project was designed to determine:

- If PSTA systems could be constructed (viability),
- If such constructed wetlands could achieve the level of phosphorus reduction desired (effectiveness) and if so,
- Whether the treatment performance could be sustained for long time periods allowing cost-effective integration of PSTAs with other treatment technologies (sustainability).

1.2 Research Challenges

The PSTA Research and Demonstration Project contains four central challenges:

- **Development, design, and testing of a relatively new natural treatment concept for nutrient removal**—this P treatment concept must successfully overcome a series of hurdles before it can be accepted as an advanced treatment technology to meet EFA requirements

- **Design and operation of experimental and field-scale mesocosms for PSTA concept development**—these mesocosms must be scientifically valid, and practical and economical to implement; due to time limitations, they must be effective from the start of the project, and must be able to operate consistently and provide valid scientific data

- **Development of a model and other predictive tools (spreadsheet, regressions, etc.) to allow extrapolation of information from mesocosm-scale studies for application to full-scale design and economic estimates**—this model must be simple enough to accurately calibrate as well as inclusive enough to incorporate external and internal factors that might significantly influence full-scale PSTA performance

- **Scientific and public scrutiny**—results from this project will receive careful examination by project proponents and detractors; research data and forecasted performance must be able to back up the conclusions of this work

1.3 Research Overview

A two-phased approach was adopted to address the stated objectives of the PSTA concept evaluation: an Experimental Phase (Phase 1), and a Validation/Optimization Phase (Phase 2). The two phases, and the types of activities that are included in each, are described as follows:

- **Phase 1 (Experimental Phase)** will include development of the preliminary work plan and experimental design, initial research in three experimental test cells (PSTA Test Cells) located at the southern end of the Everglades Nutrient Removal (ENR) project (see SFWMD 2000 for location of sites), and construction and startup/monitoring of research using 24 portable experimental mesocosms (Porta-PSTAs). The Phase 1 experimental studies will yield critical information needed to plan for field-scale mesocosm (Field-Scale PSTAs) design and construction in Phase 2. Development of a forecast model and associated predictive tools are also planned for Phase 1, along with preliminary model calibration with the Phase 1 experimental data.

- **Phase 2 (Validation/Optimization Phase)** will include continuing research in the PSTA Test Cells and in the Porta-PSTAs, and new studies at the Field-Scale PSTAs to be constructed immediately west of STA 2. During Phase 2, the expanding PSTA performance database will be used to validate the performance forecast model, and to develop design criteria for a full-scale PSTA system. The forecast model will be applied to provide projections of the long-term cost of implementing PSTAs to meet ultimate P reduction goals under the EFA.

Specific research methods for the PSTA demonstration program are described in the following sections of this *PSTA Research Plan.* These methods represent the current concepts for research and decisionmaking; however, the detailed scope of this program will continue to evolve and adapt to experimental results as they are summarized and reviewed with the District, the PSTA Scientific Review Panel (SRP), and other entities participating in review of ongoing studies of alternative advanced treatment technologies. If substantive scope emphasis shifts or new topics in need of investigation are identified, the District and CH2M HILL will work closely in adjusting scope and budget allocations to accomplish prioritized program objectives to the extent achievable within contractually defined time and resource constraints.

1.4 Research Plan Organization

Section 2 of this document details the research and design issues that are being evaluated during the course of this Research and Demonstration Project. The experimental plan for mesocosm design, construction, and operation is described in Section 3. The details of how these design issues are being addressed by the Phase 1 experiments (three ENR Test Cells and Porta-PSTA mesocosms) and the Phase 2 studies (ENR Test Cells, Porta-PSTA mesocosms, and Field-Scale PSTAs west of STA 2) are described in Sections 4, 5, and 6.

A sample collection and data analysis plan is presented in Section 7, and a discussion of the development of a PSTA performance forecast model is provided in Section 8. Lastly,

Section 9 describes the project documentation to be generated during the course of this study. A copy of the current version of the Quality Assurance Project Plan (QAPP) is provided in Appendix A. The current Site Safety Plan is provided as Appendix B. Detailed Standard Operating Procedures (SOPs) for site maintenance, operation and sample collection are provided in Appendix C. Appendix D provides the Standard of Comparison Sampling Plan and the Porta-PSTA Mass Balance (Destructive) Sampling Plan.

SECTION 2

PSTA Research and Design Issues

2.1 Key Technical Issues

A full-scale PSTA project must be able to consistently reduce water-column concentrations of TP by sequestering this nutrient in a semi-stable state or by removing it from the system through harvesting of sediments or biota. If P harvesting is required, the frequency of system shut-down to harvest accreted TP must be low enough to be practical from a cost and environmental standpoint.

The key technical issues related to full-scale project design are:

- Basic periphyton ecology, including successional patterns of biomass production, gross and net carbon fixation rates, sloughing and export rates under varying physical and successional conditions, and decomposition rates
- P uptake rates, release rates, transformations between biotic and abiotic forms, and turnover rates
- The net accretion rate of permanently bound P from all sources (sedimentation of particulates and periphyton litterfall) in the PSTA, and the maximum total accretion of P in the PSTA before the system needs to be rejuvenated (effects of successional development on net accretion rate)
- The long-term average water-column TP achievable in a PSTA discharge, including effects of flow velocity, inlet TP concentrations, water depth, outlet structure design, diel patterns, seasonal patterns, climatic events (e.g., droughts and hurricanes), and stochastic variability
- The benefits/disadvantages of periphyton/macrophyte interactions in PSTAs
- The benefits/disadvantages of calcium-rich vs. organic soil in PSTAs
- The effect of consumer organisms (such as snails and crayfish) on periphyton standing crop and P accretion rates
- The minimum and maximum cell sizes for PSTA based on flow velocity limitations
- Marsh-readiness of PSTA-treated waters in terms of the potential to create undesirable changes to natural Everglades biota

The *PSTA Research Plan* outlines the research necessary to address these key technical design issues within contractually defined constraints and resources based on the existing schedule. Further discussion of these issues and the applicable relevant experimental hypotheses is provided below.

2.1.1 Periphyton Ecology and Measurement

The periphyton (also referred to as *aufwuchs,* and including benthic algae) is a complex assemblage of attached-growth algae, tychoplankton, fungi, bacteria, and invertebrates that grows in shallow aquatic environments in response to sunlight (Vymazal, 1995). Everglades-based periphyton can be operationally sub-divided into the following groups: floating mats, epiphyton (growing on plant surfaces), metaphyton (growing in the water column and not attached to surfaces), and epipelon or benthic (growing in contact with the sediments) (McCormick et al., 1998). Generally, periphyton initially colonizes on surfaces of submerged macrophytes and other natural debris, such as woody vegetation, rocks, and plant litter. Following different periods of growth, some of the periphyton may float or drift from their initial attachment sites and become free-living masses (metaphyton) and floating mats.

2.1.1.1 Study Approach

A typical adapted periphyton community is as complex as any other ecosystem and includes a high diversity of primary producers, various levels of grazers and consumers, and a detrital food web (Lowe, 1996; Bott, 1996). As with other ecosystems, the periphyton can be studied as an assemblage of mutually dependent organisms (population approach) and/or based on overall ecological form and function (systems-level or "green-box" approach). Studies focused solely on the algal component of the periphyton are not inclusive enough to assess the function of the entire ecosystem of producers and consumers, and their net effect on TP assimilation. Some knowledge of the populations of periphytic algae and associated heterotrophs is necessary to tie this research to the existing literature on Everglades periphyton ecology, and to provide answers to some of the questions relevant to PSTA design. This *PSTA Research Plan* describes an experimental and engineering approach that places priority on measurements of system-level properties of the periphyton, when appropriate, and only recommends population-level measurements when necessary.

2.1.1.2 Periphyton Measurements

An understanding of the ecology of periphyton colonizing PSTAs is essential for development of forecast models and design criteria. Identification of dominant species allows for use of existing scientific literature to understand life histories and growth requirements. Measurement of biomass and P fractionation of the periphyton allows calibration of critical model compartments. Additionally, estimation of production, respiration, and community turnover rate allows the extraction of detailed rate constants crucial for a process-based mechanistic PSTA forecast model.

Periphyton succession will be documented through a combination of population and system-level measurements. Population-level measurements will include species identification of dominant algae and invertebrates, and cell counts over typical successional periods for each type of periphyton assemblage over a range of seasonal conditions. Identification and cell counts will be made on mixed periphyton samples collected by coring the entire mesocosm water column (see Appendix A for method details). Periphyton populations will not be studied on artificial substrates, such as glass slides, because these devices commonly underestimate natural periphyton biomass and diversity (Swift, 1982); however, mesocosm walls may be periodically sampled to quantify the effect of this artificial surface area on overall mesocosm ecological function. System-level measurements

of periphyton community structure will include routine sampling for chlorophyll *a*, *b*, and *c*, phaeophytin, wet volume, dry weight biomass, ash-free dry weight, and ash content.

Periphyton gross and net production will be measured using diurnal dissolved oxygen (DO) changes, corrected for atmospheric diffusion (Odum, 1956; Odum and Hoskins, 1957). Nighttime respiration will be estimated from oxygen rate-of-change curves during dark hours. The productivity:respiration ratio will be calculated by dividing gross production by 24-hour respiration rates. These community-level metabolism measurements are indispensable for determining turnover rates for this ecological community. Net production of periphyton will also be cross-checked by net community biomass changes over time. Community respiration rates will be cross-checked against periphyton decomposition rates.

Sloughing and downstream export of periphyton will be measured by filtration of samples of water exiting experimental PSTAs. Ample outflow water volumes will be filtered to measure particulate matter export and to analyze this particulate matter for TP, dry weight, ash-free dry weight, ash content, algal dominant species composition, and cell numbers.

Periphyton decomposition rates will be estimated using decomposition chambers made of polyvinyl chloride (PVC) pipe with mesh-covered ends. Dried periphyton material will be weighed and placed into a number of decomposition chambers, and then returned to the experimental PSTA environment for varying intervals to allow for measurement of weight loss and TP composition changes over time.

2.1.2 Periphyton/Macrophyte Interactions

In natural Everglades ecosystems and in other aquatic environments, periphyton and wetland macrophytes are intimately connected. Periphyton typically grows on the surfaces of macrophytes, providing increased attachment resources in otherwise two-dimensional environments (Browder et al., 1994; Duke Wetland Center, 1995; Vymazal and Richardson, 1995; McCormick et al., 1998). Macrophytes are also known to release cell fluids or exudates, which contain nutrients that stimulate periphyton growth (Wetzel, 1983; Burkholder, 1996). In many macrophyte-dominated wetland and aquatic environments, periphyton are known to contribute a significant portion of the total primary productivity. This contribution to the autotrophic food chain is especially important in Everglades slough ecosystems (Browder, 1995).

It is hypothesized that sparsely vegetated macrophyte beds support significantly higher periphyton productivity on an areal basis compared to open water because of increased surface area for colonization. However, at higher macrophyte densities, light attenuation from shading results in reduced periphyton productivity (Grimshaw et al., 1996; McCormick et al., 1998). Determination of the optimal macrophyte density will be important for maximizing PSTA removal of P. The importance of this relationship for the periphyton-dominated ecosystems of the Everglades is highly relevant to the PSTA concept and has not been fully documented.

The PSTA Research and Demonstration Project will document the overall effect of this interaction through the incorporation of low-density macrophyte planting in experimental units. Candidate plant species that will be tested are *Eleocharis cellulosa* (spikerush), an emergent macrophyte, and *Utricularia* spp. (bladderwort), a submerged aquatic plant. Both of these wetland plant species are known to support significant periphyton populations

(Vymazal and Richardson, 1995; Havens et al., in review; McCormick et al., 1998). PSTA experimental controls, without low-density macrophytes and periphyton, will be tested to understand the net contribution of the periphyton and macrophytes that may colonize full-scale PSTAs. These experiments will be conducted at the experimental mesocosm scale.

Macrophyte colonization of full-scale PSTAs may be inevitable. High macrophyte density is likely to lead to replacement of an algal-dominated treatment unit to a treatment wetland similar to the existing STAs. Macrophyte colonization rate and growth rate, as well as dominant species, will be thoroughly investigated in the experimental PSTAs at all three experimental scales. These studies will help to determine the nature and speed of macrophyte colonization, and may indicate practical methods to manage macrophytes in a PSTA environment.

2.1.3 Importance of Calcium-Rich/Organic Soils to PSTAs

As originally envisioned (Doren and Jones, 1996), PSTA systems would utilize calcium-rich substrates (shellrock, limerock, or weathered limestone) to increase the opportunity for P mineralization, and to decrease the rate of macrophyte invasion and the eventual shading of periphytic algae plant communities. For these reasons, PSTA construction may require excavation and removal of existing organic peat soils to expose underlying limestones, which would add a significant cost to using of PSTAs for P treatment. Because of the existing uncertainty of the importance of soil type to PSTA performance, a test of effects of differing soil types on P accretion and plant growth will be conducted in the experimental mesocosms and ENR PSTA Test Cells, and will be demonstrated in the field-scale facility.

Experimental mesocosms will include organic peat-based and calcium-rich soils (shellrock and limerock), sand soils and non-soils. Five conditions will be tested at the experimental mesocosm scale. These include cells with shellrock native to the project area, and cells with organic peat soils native to the project area. The ENR PSTA Test Cells will duplicate the treatments with shellrock and peat soils. Phase 2 research will use soil type as a treatment variable in an effort to determine a preferred substrate.

2.1.4 Net P Accretion Rate

It is hypothesized that the only significant, long-term P removals that are possible with the PSTA design are:

- Long-term net transformation and accretion of water-column P, as chemically or organically bound P in the PSTA sediments
- Sediment and periphyton harvesting and disposal outside the PSTAs

Other possible P sinks, such as export in consumers, release of phosphine gas to the atmosphere, or losses to groundwater, are either not likely to be of an adequate quantitative magnitude or, as in the case of groundwater seepage, may not be viewed as an acceptable environmental solution. The ability of PSTA technology to sequester P through internal storages is being quantified to assess life expectancy and cost-effectiveness.

The net P accretion rate will be assessed for all of the experimental systems through inflow/outflow water sampling, periphyton and sediment sampling and P fractionation,

and resulting P mass balances. Sediments will be sampled from experimental PSTA systems and will be analyzed for available and unavailable P. Sorption/desorption studies will be conducted with both calcium-rich and organic sediments at the beginning of the studies, and after a period of PSTA operation, to determine the potential for initial P releases and saturation of sorption sites. Typical water-column profiles will be harvested with clear plastic cylinders, and the samples will be visibly fractionated between the sediment surface and the living periphyton community. Changes in total sediment P will be compared over time to net changes of TP between inflow and outflow waters from the experimental systems to check the overall TP mass balance for the experimental PSTAs. Total losses of TP in the field-scale mesocosms (Phase 2) will be corrected for groundwater inflow and outflow by water balance information and piezometer samples of TP concentration.

The net accretion rate of P in PSTAs is likely to vary through time in response to varying patterns of solar intensity, air temperature, periphyton species composition, macrophyte population density, community productivity, plant senescence, grazing, precipitation/sorption, and export. Experimental systems will be run as long as possible within the scope of this project to help define long-term successional and seasonal patterns for PSTA design. Previous research has indicated that periphyton net production and accrual are maximum during successional community development and lower under mature conditions (Knight, 1980). The effect of this ecosystem-level response on TP removal may result in the need for periodic disturbance of PSTA periphyton communities to maintain high accretion rates.

2.1.5 Physical Constraints on Full-Scale PSTA Design

Design of full-scale natural treatment systems must consider the effects of physical size, cell number and configuration, potential peat removal and disposal, levee construction, seepage and recollection, flow velocity effects on sediment resuspension and periphyton sloughing, water depth regime, hydraulic optimization, and biomass/sediment harvesting and disposal. Most of these issues can be evaluated during testing of field-scale mesocosm systems. Field-Scale PSTAs will be large enough to assess constraints related to muck removal and use as PSTA cell embankments. Water balances on Field-Scale PSTA units will document groundwater losses, both with and without muck removal and capping the peat with limerock. Effects of cell configuration will be tested by use of tracer studies, with and without internal flow optimization features, such as deep zones.

2.1.6 Marsh Readiness

There is a high probability that the PSTA concept could be an element of the Phase II ECP efforts to provide water that meets the EFA target and is compatible with maintenance of downstream ecosystems in the Everglades. No chemicals will be added and little disturbance is anticipated. Algal-dominated systems are known to alter pH and DO conditions, but relatively wide variations of these parameters are typical of Everglades slough environments (Duke Wetland Center, 1995; Vymazal and Richardson, 1995; McCormick et al., 1997). The most likely environmental impact that might result from this technology is harvesting and disposal of the periphyton biomass, assuming this is found to be necessary to maintain high TP removal rates. This impact would be confined to the PSTAs themselves and to neighboring lands where the plant material is dried and disposed of. Disposal of this side-stream material would need to be conducted with caution to minimize the potential for ancillary water-quality impacts.

An additional issue of concern is the potential that PSTAs may contribute to increased mercury availability through methylation. Anaerobic environments appear to be the primary locus for formation of methylated mercury compounds. Highly productive periphyton communities (as well as macrophyte-dominated wetlands) may have anaerobic sediments. Existing mercury in these sediments or mercury entering PSTAs from atmospheric deposition might be transformed into these problematic compounds.

The PSTA Research and Demonstration Project will be evaluated using FDEP protocol for assessing marsh readiness (FDEP, 1997). This testing includes whole-effluent toxicity tests and mercury sampling, and will be conducted during Phase 2 of the research and demonstration project after definition of an "optimal" PSTA concept. The Standards of Comparison (STSOC) sampling plan is provided under Appendix D.

2.2 Hypothesis Identification

The primary objective of the PSTA research program is to address the following three critical issues:

- **Viability** refers to establishment and maintenance of the desired periphyton-dominated ecological community. Although the location of periphyton-dominated ecosystems in the Everglades is known, there is a need to refine the basic understanding of how to create this ecosystem, how long it takes to establish mature periphyton communities, and how to maintain these systems against shifting dominance by macrophytes (floating, submerged, or emergent) and phytoplankton (free-floating algae).
- **Effectiveness** refers to the ability of a PSTA to consistently and predictably remove P. Net P removal is dependent upon sustainable gross P removal rates, chemical and biological transformations of the P into non-reactive forms, and ultimate burial of P in newly accreted sediments or biomass. A number of design considerations are likely to determine the effectiveness of a full-scale PSTA. These include such factors as flow velocity, water depth, presence/absence of macrophytes at low densities, and the nature of underlying antecedent soils.
- **Sustainability** refers to the long-term maintenance and operational cost of a periphyton-dominated treatment system. Will these systems require frequent or rare intervention for removal of accreted P? Will they restart and operate smoothly after a dry-down or flood event? Will they create water quality problems downstream in receiving waters from release of chronically or acutely toxic environmental pollutants, such as methylmercury?

The following research hypotheses are related to the three critical issues described above, and will be tested by one or more of the research components:

Hypothesis #1: PSTAs can be colonized and operational in less than 1 year following basin construction (viability).

The rate of periphyton colonization in newly constructed PSTAs is not currently known; however, measured periphyton productivity rates are relatively high (2 to 15 grams per

square meter per day [g/m^2/d]). Assuming a high ratio of productivity:respiration during initial colonization, a sustainable biomass of >200 g ash free dry weight per square meter (AFDW/m^2) is expected to develop within 3 to 6 months. Porta-PSTAs will be "seeded" with periphyton collected from WCA 2-A. This seeding is intended to jump-start representative P accretion and experimental monitoring in a period as short as 1 month following startup, and precludes use of these experimental systems for determining the rate of colonization in full-scale PSTAs. Neither the PSTA Test Cells nor the Field-Scale PSTAs in Phase 2 will receive a large amount of seed material. Actual periphyton colonization rates in these experimental systems will be documented through biomass and percent cover changes measured over time.

Hypothesis #2: The presence of low-density stands of emergent macrophytes and submerged aquatics will increase the PSTA sustainable TP settling rate (viability and effectiveness).

Data analysis from ENR Cell 4 (submerged aquatics and sparse emergent vegetation) indicates that average monthly TP settling rates are between 0 and 80 meters per year (m/y), with an approximate mean of 40 m/y (Walker 1998). The effects of macrophyte presence/absence will be tested in the Porta-PSTA mesocosms by performing an analysis of variance, using TP removal rate constants as the response variable. Effects of macrophyte presence/absence will be tested in the Porta-PSTA mesocosms through comparisons of TP rate constants between the vegetated and unvegetated test units.

Hypothesis #3: Substrate type significantly affects PSTA sustainable TP settling rate (effectiveness).

The PSTA concept as described by Doren and Jones (1996) relies on removal of organic soils and the direct interaction between overlying water and a calcium-rich underlying substrate. However, it is likely that substrate-water column interactions will decline with system maturation as internally produced residuals are deposited over the original soils. Effect of substrate type will be tested in the Porta-PSTAs by performing an analysis of variance on the mesocosm experiments to determine the effects of substrate, using TP settling rate as the response variable. Substrate effects in the PSTA Test Cells will be performed by comparisons of cells with and without shellrock added, and similar comparisons will also be incorporated in the Field-Scale PSTA studies.

Hypothesis #4: The sustainable TP settling rate for PSTAs is >35 m/y (effectiveness).

Sustainable TP settling rates in the WCAs, the ENR, the STAs, and in numerous other emergent macrophyte wetland treatment systems range from 10 to 20 m/y. Limited data from PSTA-like wetlands indicate that TP settling rates may be in the range of 20 to 180 m/y (Kadlec, 1996a). TP settling rates will be measured at all three experimental scales by calculating system average first-order settling rate constants.

Profiles of TP concentrations measured over a longitudinal gradient in treatment wetlands are readily described by a first-order logarithmic decay with a background value (Kadlec and Knight, 1996). A two-parameter model (k-C* model) has typically been used to duplicate this type of gradient TP response. TP settling rates will be determined by differences in water samples collected weekly between the inlet and outlet of each mesocosm in Porta-

PSTAs, PSTA Test Cells, and Field-Scale PSTAs. Water samples will be collected quarterly along longitudinal gradients in the experimental PSTAs to provide additional curve-fitting power for determining net TP accretion rate as a function of treatment. Differences in TP settling rate constants between replicate mesocosms, treatments, sampling events, seasons, or other time period variables will be screened using graphical plotting techniques and statistical tests. Differences in TP rate constants over time will be tested by analysis of covariance, with sampling date as the covariate. If no differences in rate constants appear in the plots and statistical tests, the data for each treatment will be pooled over the study time period for regression analysis. Statistical tests for differences in TP settling rates will then be performed across treatments. Tests for differences in linear regression slope coefficients can be performed using standard F-ratio tests and t-tests in the context of an analysis of covariance, such as described in Sokal and Rohlf (1981, sections 14.8 and 14.9) and Montgomery (1997, section 4-7). Differences in regression intercept coefficients can also be tested in this analysis, although none are expected. A difference in intercept coefficients between treatments would indicate a difference in initial TP concentration, but is not expected given that all of the mesocosms are receiving inflow from the same source and should start out with the same initial TP concentration.

Hypothesis #5: PSTA annual average TP export can be sustained below 10 mg/L (effectiveness).

Ambient TP in Everglades areas colonized by periphyton-dominated plant communities are in the range of 5 to 15 micrograms TP per liter (µg TP/L) (McCormick et al., 1996). All three experimental scales will provide information concerning sustainable TP export concentrations. Annual average TP concentration in the effluent of the mesocosm structures will be calculated and combined with a one-sided ("one-tail") hypothesis test comparing the annual average of the observed data to the threshold value of 10 µg/L, with the null hypothesis (H_0) and alternative set up (H_a) as follows:

H_0: The annual $\bar{x}$ of [TP] $\geq$ 10 µg/L
H_a: The annual $\bar{x}$ of [TP] < 10 µg/L

In addition, the results of the forecast model used to predict annual average TP concentration will be used to test the hypothesis, supported by statistical evaluation as outlined in the section on model verification below.

Hypothesis #6: PSTA maximum monthly average export TP can be sustained at less than 2 times annual average TP export (effectiveness).

The average ratio between TP maximum month and annual average for 43 treatment wetlands is 1.8 (Kadlec and Knight, 1996). The current value of this ratio for the ENR is approximately 1.5 (Walker, 1998). All three experimental scales will provide information concerning export TP concentration variability. The average monthly maxima for each experimental treatment will be compared using a one-sided ("one-tail") hypothesis test to the threshold value of 20 µg/L, with the null hypothesis and alternative set up as follows:

H_0: The monthly $\bar{x}$ of maximum [TP] $\geq$ 20 µg/L
H_a: The monthly $\bar{x}$ of maximum [TP] < 20 µg/L

Hypothesis #7: PSTA TP export concentration is highly correlated with hydraulic loading rate for a given TP inflow concentration (effectiveness).

Hydraulic loading rate (HLR) is the best single correlate for outflow concentration in treatment wetlands (Kadlec and Newman, 1992; Kadlec and Knight, 1996). TP settling rate may be correlated with HLR in treatment wetlands because of mass loading and TP concentration effects. Effects of HLR on TP export concentrations will be tested at the Porta-PSTA experimental scale, with planned HLRs in replicated mesocosms of 6 and 12 centimeters per day (cm/d) (see Section 5). The analysis of variance with repeated measures (over date) will be used, with TP-Removed or the TP rate constant as the dependent variable, and hydraulic loading as a covariate.

Hypothesis #8: PSTA sediment and macrophyte biomass accretion rates will dictate major operation and maintenance requirements in less than 10 years (sustainability).

Sustainable TP removal rates require a sink, such as sediment accretion. Increasing organic sediment depth may encourage increased colonization of macrophytes in PSTA cells, therefore converting these systems to emergent macrophyte-dominated wetlands with lower sustainable TP settling rates. Sediment accretion rates will be measured with horizon markers at all three mesocosm scales; significant differences between Porta-PSTA treatments in sediment P accretion will be determined by analysis of covariance, with time as the covariate. Also, results from the performance forecast model will be used to predict the long-term ability of PSTA systems to remove TP. The model will be used as the main tool to test the hypothesis, supported by statistical evaluation for the model verification exercise. Statistical support for model verification is described in Section 8.3.

Hypothesis #9: Flow velocity exhibits a subsidy-stress effect on the PSTA sustainable TP settling rate (effectiveness).

PSTA physical size has a significant effect on surface water flow velocities. As the size of parallel treatment cells increases for a given HLR and residence time, flow velocity increases proportionally. Flow velocity is known to effect periphyton growth with respect to community thickness, species composition, and primary productivity (Stevenson and Glover, 1993; Stevenson, 1996; Ghosh and Gaur, 1998). Current velocity has been shown to increase periphyton productivity at low levels and to reduce productivity at higher levels. The potential subsidy-stress effect of linear velocity on TP settling rate cannot be directly measured in the experimental mesocosms being used for the PSTA research project. For example, average current velocity at an average HLR of 6 cm/d and a depth of 50 cm at different experimental scales, will result in average nominal flow velocities of only 0.6, 8.0, and 10.8 m/d (see Sections 4, 5, and 6). These velocities are much lower than velocities that would result in full-scale PSTAs. For example, a 200-hectare (ha) PSTA with length:width ratio of 2, an average water depth of 60 cm, and an HLR of 6 cm/d would have an average linear velocity of 100 m/d. Short-term studies will be used to determine the effects of high flow velocities on periphyton ecology using the Porta-PSTA mesocosms. Community production, respiration, and export will be measured under these increased flow rates, and physical effects on the periphyton community will be visibly assessed.

Hypothesis #10: Water depth in the range between 30 and 60 cm does not significantly affect PSTA sustainable TP settling rate (viability and effectiveness).

Treatment wetland research has found that TP settling rates are largely independent of depth between 30 and 60 cm (Kadlec and Newman, 1992). Benthic periphyton have highest productivity when water depths are shallow (less than 30 cm) because of light attenuation in colored water. Overall periphyton community biomass and productivity, including epiphyton, metaphyton, and floating mats, may not differ between shallow and deep mesocosms if sparse emergent macrophytes are present, and periphyton can colonize the upper portion of the water column. There is currently a lack of empirical evidence concerning the effect of water depth on the sustainable TP accretion rate in periphyton-dominated wetlands.

A second issue related to the water-depth hypothesis is the effect of dry-down on sustainable TP accretion rate. Full-scale PSTAs can be expected to have highly variable inlet hydrologies with periods of no inflow, and subsequent drying from evapotranspiration and seepage. Dry-down may be an essential component of P fixation in inactive forms (Jones, 1996; Kadlec and Walker, 1996), although concern has been expressed that re-wetting of dry PSTAs may be impractical because of normal climatic variability, or may result in resolubilization and wash-out of labile P (Kadlec and Walker, 1996).

Experimental mesocosms and the PSTA Test Cells will be designed to allow operation at different water depths, ranging from the sediment surface to a maximum of 100 cm in the PSTA Test Cells. The additional effects of transverse deep zones will be examined in the Field-Scale PSTAs. These deep zones are commonly used in treatment wetlands to enhance performance (Kadlec and Knight, 1996). Their inclusion in a full-scale PSTA has the potential to significantly change average water depth.

Operational water depth is a key variable for the Porta-PSTAs and the PSTA Test Cells (see Sections 4 and 5). Constant water depths of 30 and 60 cm will be tested in replicated Porta-PSTAs during Phase 1. In addition, two treatments will test the effect of depth variation on Porta-PSTA performance. These treatments will receive a "typical" annual cycle of flow rates with an average of 6 cm/d, and will have their outlet elevations varied over this seasonal pattern to simulate a dry-down during the normal dry season. One PSTA Test Cell will also be operated with varying water depth and dry-down, while the other two cells will have a constant operational depth of either 30 or 60 cm.

Hypothesis #11: Outflow water from full-scale PSTAs will not be chronically toxic to indigenous Everglades flora and fauna and will not include unacceptably high concentrations of methylated mercury (sustainability).

There are currently few data on the acute and chronic toxicity of natural Everglades slough waters. Phase 2 PSTA testing will indicate the extent to which PSTA effluents exhibit whole-effluent toxicity. Furthermore, sampling for methylmercury will be conducted during Phase 2 to determine if these compounds are being elevated by the passage of surface waters through PSTA cells.

SECTION 3

Experimental Design

3.1 Relevant Research and Technical Review

3.1.1 Mesocosm Experience Workshop

The District and other agencies and scientists have been conducting research programs involving the use of mesocosms for varying lengths of time in the Everglades, WCAs, and Lake Okeechobee to evaluate candidate advanced treatment technologies for the ECP and to improve understanding of subtropical ecosystems in Florida. As a result, other consultants and District staff have accumulated significant practical understanding that may be useful to the PSTA Research and Demonstration Program. A 1-day workshop was held at the District on June 25, 1998, to bring researchers together to describe their experimental designs. This workshop was successful at providing verbal briefings and supporting information from District staff and consultant teams regarding other mesocosm design, construction, and study monitoring conducted under the auspices of the overall advanced treatment technologies program, or directly relevant research by other entities.

The most relevant mesocosm research facilities that were described include:

- Duke University Wetland Center WCA 2A *in situ* flume studies (Dr. Curtis Richardson)
- District WCA 1 and 2A *in situ* Periphyton Mesocosms (Dr. Paul McCormick and Chad Kennedy)
- ENR Macrophyte Tank Study (Dr. Susan Newman)
- Lake Okeechobee Periphyton Mesocosms (Dr. Karl Havens)
- Submerged Aquatic Vegetation (SAV)/Limerock Demonstration Project Mesocosms (Dr. Tom DeBusk)

Published data on design, methods, and performance of all these systems are available, and were reviewed during preparation of the first draft of the *PSTA Research Plan* (August 1998).

3.1.2 Scientific Review Panel Research Plan Review

A PSTA SRP was convened to provide review of the *Research Plan*, data collection, data analysis, and interpretation of results. A preliminary draft of this *PSTA Research Plan* was sent to the SRP on August 12, 1998, and the group convened in West Palm Beach, Florida, on August 21, 1998, to discuss the preliminary *Research Plan* and to offer suggested revisions. Participants at the initial SRP meeting, with the exception of the project consultants, included:

- SRP Members
  - Dr. Jan Stevenson, Michigan State University
  - Dr. Jan Vymazal, Ecology and Use of Wetlands
  - Dr. K. Ramesh Reddy, University of Florida Institute of Food and Agricultural Sciences
- District
  - Dr. Susan Gray
  - Dr. Mike Chimney
  - Dr. Paul McCormick
  - Dr. Al Steinman
  - Lori Wenkert
  - Dave Swift
  - Dr. Jana Majer-Newman
  - Tammy Lynch
  - Kathy Pietro
  - Drew Campbell
  - Greg Coffelt
  - Christy Combs
- USACOE
  - Peter Besrutschko
  - Ed Brown
- Other Affiliations
  - Dr. Ron Jones, Florida International University, Miami, FL
  - Dr. Robert Kadlec, WMS, Chelsea, MI

A fourth SRP member, Dr. Robert Wetzel, University of Alabama, Tuscaloosa, AL, was not able to attend the meeting in person, but provided written comments on the preliminary draft *Research Plan* prior to the meeting as well as oral comments via conference call after the meeting.

Project objectives, research hypotheses, and experimental and model design to address those questions were the focus of the 1-day meeting. The meeting agenda included:

- Project overview and objectives
- Sampling methods and materials
- Forecast model
- Other topics

Each of these agenda items was discussed in considerable detail within the 1-day meeting format. Substantive input was received on dozens of issues. A list of the principal results of this review process includes:

- Porta-PSTA design and construction – use of translucent wall material other than glass; fiberglass was preferred; significant input received on recommended treatments, mesocosm size, replication, and scale-up effects
- ENR PSTA experimental design—duplicate three Porta-PSTA treatments
- Field-Scale PSTAs—postpone design until end of Phase 1
- Sampling methods and materials—considerable input on P fractionation methods, periphyton sampling techniques, diel sampling, and ancillary water chemistry parameters
- Performance forecast model—discussion of Level II draft model and velocity effects

An SRP conference call was held on August 5, 1999; additional SRP meetings have been held to date on:

- August 21-22, 1998
- December 3-4, 1999
- September 9-10, 2000
- January 14-14, 2001

Specific outcomes of these meetings and subsequent written comments from SRP and District technical reviewers have been carefully considered, and included where appropriate throughout this revised *PSTA Research Plan*.

3.2 Experimental Design Issues

The experimental design described in this section includes the use of mesocosms, which are reduced-scale outdoor experimental ecosystems (Kangas and Adey, 1996). Three types of mesocosms are being used to test the PSTA concept: experimental-scale (Porta-PSTAs and ENR Test cells) and field-scale. The key differences between these two scales is that experimental-scale mesocosms are smaller, can be practically replicated and manipulated, may be portable, can be cleaned and restarted with minimal cost, and require less money and water flow to operate. In contrast, field-scale mesocosms are built in-ground and address engineering and ecological conditions of full-scale systems. These larger-scale systems serve as excellent visual demonstrations of the full-scale technology application, but pose special research challenges because they are typically difficult to replicate, manage, and manipulate effectively, and are costly to construct and restart.

All mesocosm-scale systems have certain limitations for scale-up to full-scale design (Bowling et al., 1980; Beyers and Odum, 1993). Reduced-size systems may have unrealistic surface area to volume ratios and flow velocity regimes. Both of these factors can have significant effects on system performance and life expectancy. Scale-up limitations will be estimated as part of the proposed PSTA test project data collection and analysis.

Design of the experimental- and field-scale mesocosms for the PSTA research project is dictated by factors related to research goals and existing constraints. Research hypotheses,

goals, and objectives were described in Sections 1 and 2; project constraints include space, budget, and time. ENR PSTA Test Cells are already designed and constructed, and contain minimal flexibility for design modifications. Substrate was installed in the three allocated ENR Test Cells at the southern site to the preliminary specifications of the PSTA experimental design in July 1998. There is no flexibility to change that basin design at this time.

Experimental-scale Porta-PSTAs will be located at the ENR outflow location within a limited area and with a limited budget. A review of alternative mesocosm design and material options indicated that a maximum of 24 Porta-PSTAs, varying in size from 6 to 18 m^2, could be constructed during Phase 1. PSTA Test Cells will be constrained to the existing District Test Cells at the south ENR site. These systems have a surface area of approximately 0.22 ha (0.55 acre [ac]).

Field-Scale PSTA mesocosms will be constructed west of STA 2 and within a limited budget. Within these constraints, and based on Phase 1 experimental results, four Field-Scale PSTA cells, each with an area of 2 ha (5 ac) will be constructed to assess PSTA scale-up and constructability issues.

The strengths and limitations of mesocosms for providing relevant design guidance have been briefly described above. An understanding of these constraints is essential to optimize the amount of useful information derived from the PSTA research effort. A number of very specific issues are relevant to design of mesocosms described in this Plan. These issues are:

- Mesocosm size and configuration including surface area, length, width, aspect ratio, flow velocities, water depth, volume, surface:volume ratio, inlet and outlet flow distribution, temperature, and replication
- Mesocosm construction including materials selection, water integrity, soil selection and depth, water feed, water depth regulation, and instrumentation/monitoring access
- Mesocosm operation including hydraulic loading and residence time analysis, feed water source, , periphyton seeding, macrophyte planting, startup, sampling methods and materials, experiment duration, and data analysis

The relevance of each of these issues to mesocosm design is discussed below.

3.2.1 Mesocosm Size and Configuration

3.2.1.1 Surface Area

Surface area is the single most important design determinant of wetland performance—more important than water depth or volume—because of its proportionality with external driving forces (sunlight, wind, gaseous diffusion, etc.) and with the resulting biological communities (Kadlec and Knight, 1996; Duke Wetland Center, 1997). Extrapolating this conclusion from treatment wetlands, it is hypothesized that surface area is also an important factor in PSTA design. Performance data are currently lacking comparing the performance of PSTA systems as a function of surface area and volume.

If all design variables were only a function of surface area, then any size mesocosm could be used to scale up to a full-scale PSTA. However, it is well known that physical factors

important to PSTA performance change in magnitude as a function of mesocosm surface area (see Sections 3.2.1.3 and 3.2.1.4 for discussion of flow velocities and surface:volume ratio, respectively). Therefore, to eliminate the need to estimate scale-up factors for different size mesocosms, it would be preferable to build test systems at the same scale as full-scale systems. This preference is impractical for the PSTA research project because of budget and time constraints. Therefore, it is necessary to take a practical approach to build mesocosm-scale test systems that meet budgetary constraints, while being aware of potential scale-up limitations.

The area of the ENR PSTA test cells available for this project is predetermined with three cells, each with an area of 0.22 ha (0.55 acre [ac]). The Porta-PSTA mesocosm areas are 6 m^2 for 22 of the tanks and 18 m^2 for the two larger tanks. The Field-Scale PSTA cells have an area of 2 ha (5 ac) each.

3.2.1.2 Length, Width, and Aspect Ratio

PSTA cell length, width, and aspect ratio (length:width ratio) are interdependent. Because wall or embankment construction is the dominant expense item, the least expensive cell to construct is generally circular or square, with an aspect ratio of one (Knight, 1987). Higher aspect ratios have been used in treatment wetlands to try to increase hydraulic efficiency and performance. Research from constructed treatment wetlands indicates that increased aspect ratio has no consistent beneficial treatment effects (Kadlec and Knight, 1996). It is considered likely that aspect ratio will not be a critical design parameter for PSTAs with the possible exception of the effect of this variable on linear flow velocity (see below).

3.2.1.3 Flow Velocity

Aspect ratio can be varied to simulate a gradient of hydraulic and pollutant loading rates and to affect longitudinal flow velocities. For a given hydraulic residence time (HRT), the average flow velocity (w) is directly proportional to cell length (L) based on the relationship:

$$w = L/HRT$$

If the HRT is held constant by holding the cell area and depth constant, then flow velocity is inversely proportional to cell width (W):

$$w = L/HRT = (A/W)/HRT = (1/W)(A/HRT)$$

Flow velocity is known to affect periphyton in two ways: replenishment of growth nutrients and removal of waste products, and creation of sloughing and downstream export (Stevenson, 1996). Periphyton community development is clearly a function of flow velocity. No reduced-scale experimental system can replicate the flow velocities that might be reached in a full-scale PSTA cell without an unavoidable scale-up complication from increased HLR and/or surface to volume ratios. Therefore, a range of flow velocities well below the actual value will have to be tested in the mesocosms. Higher flow velocities typical of full-scale systems will be tested during short-term experiments in the Porta-PSTAs to observe physical effects on periphyton growth, sloughing, and export, and in the larger Field-scale cells with varying length-to-width ratios. Effects of increased flow velocities on TP removal performance will have to be estimated by comparison between mesocosm scales and with the use of the performance forecast model.

3.2.1.4 Water Depth, Volume, and Surface:Volume Ratio

Water depth affects water volume, HRT, and light penetration in PSTA systems. HRT is not always highly correlated with water depth because of the potential for short-circuiting and resulting hydraulic inefficiency. Plant stems and periphyton displace only a small volume in Everglades wetlands (generally less than 5 percent). Actual maximum water depths in natural Everglades periphyton-dominated sloughs are generally less than 1.5 m, and average water depths are typically approximately 0.6 m (Browder et al., 1994; Vymazal and Richardson, 1995).

The ratio between surface area (walls and bottom surface area) and water volume changes in proportion to mesocosm scale, and is known to affect the ability to scale results up to full-scale system responses. This effect is most extreme in small-scale experimental systems. For example, a square mesocosm 0.3 m deep with an area of 1 m^2 has nearly twice the surface area to volume ratio (ratio = 7.3 m^{-1}) as a mesocosm with a bottom area of 100 m^2 (ratio = 3.7 $^{-1}$). Higher surface area to volume typically results in higher performance estimates because of the increase in available surface areas for microbial and algal colonization.

Water depth significantly affects the depth of light penetration in waters that have dissolved organic color or particulates. Waters flowing through STAs with peat soils have increased color that might affect how a downstream PSTA might function. Benthic periphyton will not be able to grow on light-limited bottom substrates, and are only likely to predominate in shallow PSTA systems.

Full-scale PSTAs are likely to receive highly variable inputs, depending on climatic events, and may need to have the flexibility to operate under a range of water depths and continuously fluctuating water levels (Kadlec and Walker, 1996).

Floating periphyton mats and loosely aggregated metaphyton living in the water column will have the ability to out-compete benthic periphyton under both shallow and deeper water conditions. The relative importance of benthic versus non-benthic periphyton to sustainable net TP accretion in PSTAs is unknown. For these reasons, water depth is a key treatment variable in the PSTA research design.

3.2.1.5 Inlet and Outlet Distribution

Effective flow distribution is a challenge in design of any shallow impoundment treatment system, including mesocosms, whose performance is affected by hydraulic efficiency. Point inlets and outlets can result in dead zones and short-circuiting (Kadlec and Knight, 1996). Shallow water depths can result in erosion and channelization. Multi-port inlet headers, flow baffles, and inlet deep-water spreader zones can be used to increase flow distribution. Internal levees, transverse deep zones, and meticulous grading specifications can reduce internal short-circuiting. Multiple outlet structures, flow baffles, and outlet deep zones can be used to enhance flow distribution at the downstream end of shallow impoundments. Tracer studies will be used with any mesocosm system to quantify hydraulic efficiency.

3.2.1.6 Temperature Effects

Natural Everglades slough communities undergo significant temperature variation in response to insolation, water depth, and color (related to light attenuation). It is important that experimental mesocosms undergo a temperature pattern that approximates the mean

and extreme values that might be typical of a full-scale PSTA. The best existing source for information related to these values are data collected from periphyton-dominated slough communities in the Everglades region.

Diel temperature measurements at the Duke University dosing site in WCA-2A indicated daily ranges of 4 to 5°C during July and August 1995, with maximum and minimum temperatures of approximately 32.0 and 26.5°C, respectively (Duke Wetland Center, 1995). Diel water temperatures varied by approximately 6 to 14°C during October 1980 at a reference slough site in WCA-1, with a median water depth of approximately 30 to 50 cm and maximum and minimum temperature readings of 28 and 14°C, respectively, during a 5-day period (McCormick et al., 1997). During the same week at this site, the diel temperature range was approximately 2 to 4°C, and the maximum and minimum values were 21 and 26°C. The authors reported a diel temperature range from approximately 26 to 28°C at an enriched slough site in WCA-2A during August 1985.

In a comprehensive study of the three WCA-periphyton communities in 1978–79, Swift (1981) reported that the mean water temperature was 23.8°C, with an annual variation from 13.4 to 35.7°C. In the Lake Okeechobee littoral zone slough communities, Havens et al. (1996) reported water temperatures in the range of 25 to 30°C, with a maximum of 40°C recorded under a periphyton mat. Littoral mesocosms had temperatures typically between 28.2 and 30.9° C, with peaks up to 37°C and a diel change of 3 to 7°C (Havens et al., 1996).

This review indicates that Everglades periphyton-dominated ecosystems typically experience normal temperature extremes for a range of approximately 13 to 37°C, with typical diel variation between 2 to 7°C.

Preliminary temperature data are available from the SAV-limerock mesocosms deployed at the south ENR Test Cell site (DeBusk, 1998). These data indicate that in small mesocosms deployed aboveground with 30 cm water depth, the diel temperature swing varied from 2 to 7°C with maximum temperatures of approximately 34°C during July 1998, while temperature swings in the shallowest raceways (8 to 10 cm depth) were between 8 and 16°C, with frequent values of 38°C. These results indicate that the Porta-PSTA mesocosms described in Section 5 with 30 to 60 cm water depth will undergo temperature variation well within the daily and seasonal range measured under field-scale conditions in the Everglades sloughs. During dry-down studies in these Porta-PSTAs, temperature extremes typical of drying Everglades wetlands are likely to result. There does not appear to be any scientific need to try to ameliorate these natural temperature variations by use of water baths or any other technique for this research.

3.2.1.7 Replication and Controls

Experimental science dictates the need for replication and the need for experimental controls. Replication of experimental treatments allows assessment of variability and the statistical significance of results. Specifically, replication of experimental treatment combinations is necessary to produce an independent estimate of the experimental error variance necessary to perform any test of the statistical significance of treatment effects (Milliken and Johnson, 1989). In general, higher numbers of replicates allow greater statistical power for distinguishing significant differences in treatment effects, but there may be diminishing returns with increased sampling effort. Similarly, appropriate experimental controls allow

experimental artifacts and actual treatment effects to be distinguished. Various levels of controls may be required to fully separate the effects of different treatments in an experimental design.

Special challenges are inherent in implementing a sound scientific experimental design on the PSTA project. At a minimum, there is a critical need to balance the use of many, smaller mesocosms to gain statistical power with the need for more costly, larger-scale mesocosms that more readily mimic the ultimate field application. Smaller laboratory microcosms and mesocosms are easier to replicate than larger mesocosms and outdoor experimental systems. Smaller systems are also less expensive to build and monitor than larger mesocosms. Importantly, additional complexity inherent in large, outdoor mesocosms results in greater variability in experimental results and reduces the benefit of replication to distinguish significant differences (Bowling et al., 1980). Common practice in large-scale, outdoor mesocosm research eliminates replication in favor of greater numbers of samples from non-replicated treatments.

These conflicting experimental needs can be resolved if the PSTA project is viewed as containing essentially two phases: Phase 1, an exploratory phase, and Phase 2, a confirmatory phase (*sensu* Milliken and Johnson, 1989, pg. 2). In the exploratory phase, it is desirable to test as many treatment combinations as possible. The important treatment variables include substrate type (i.e., limerock vs. peat) and variable depth (0.3 m vs. 0.6 m). This has been organized as a 2 x 2 factorial (four treatments), with two additional treatments to test HLR and variable water depth for only one substrate type, resulting in six principal treatment combinations with three replicates each in the Porta-PSTA mesocosms (described in Section 5). Six additional treatments are included without replication to provide a "demonstration" of other combinations of experimental parameters, resulting in a total of 24 Porta-PSTA Test Cells.

The chosen *PSTA Research Plan* partially replicates the experimental design, with a result that there will be some mesocosms, that provide replication of the most essential treatment combinations. This approach is consistent with recommendations by Milliken and Johnson (1989), who explain that during the exploratory phase, it may be preferable to use each mesocosm for a different treatment. It is possible to estimate the experiment error variance without replicating the experimental units, but only if certain assumptions are met. It is more important to get an accurate estimate of experimental error variance when the major objective of the experiment is confirmatory.

Applying this argument presented by Milliken and Johnson (1989) to the PSTA project, the Porta-PSTA experiments can be viewed as the exploratory phase of the experimental design. Having six principal treatment combinations will provide sufficient data to use the methods of Milliken and Johnson (1989) to estimate the experimental error variance, as long as the response data are transformed to follow a standard normal distribution. Water quality variables are not usually normal (Reckhow et al., 1992), but transformation to log-normal distribution would satisfy the requirement.

Repeated measures of the experimental Porta-PSTA and ENR Test Cell mesocosms will allow for the characterization of the stochastic processes of temperature, sunlight, wind, and rain for an annual cycle during Phase 1. These repeated measures do not constitute replication of the experiments. A single mesocosm will be the experimental unit, where time

represents within experimental unit (mesocosm) variation. As described below, multiple sampling of each mesocosm on each sampling date over several locations in a longitudinal transect also does not constitute replication, but is a form of split-plot sampling design.

Phase 2, as revised per SRP recommendations in December 1999 will include continued replicated experiments for 6 months with the Porta-PSTA mesocosms. Continued investigations with the three ENR South Test Cells will occur for a second year of operations. Lastly, unreplicated investigations at the field-scale pilot PSTA level will be conducted to provide critically needed information regarding scale effects and system constructability.

3.2.2 Mesocosm Construction

3.2.2.1 Materials Selection

Mesocosms can be constructed in many different ways with many different available materials (Beyers and Odum, 1993). Material selection is dictated by concerns regarding system cost and effects on experimental results. The least expensive material that will result in the most natural or desired experimental conditions will generally be selected. Desirable construction materials for small periphyton mesocosms are transparent to sunlight to reduce shading effects, non-sorbing to eliminate chemical interactions with walls, sturdy, and inexpensive. Larger field-scale construction materials will generally be onsite soils because of cost issues.

Porta-PSTAs will be constructed from translucent fiberglass. Other materials considered were glass and acrylic (Plexiglass). Glass has the advantages of maximum light transmission and minimum chemical reactivity. It has the disadvantages of strength, weight, and safety concerns. Acrylic can be supplied in any thickness that might be required to hold necessary water volumes for the Porta-PSTAs. A typical wall thickness estimated for tanks holding approximately 4 cubic meters (m^3) of water was between 2.5 and 4.4 cm. This thickness results in high tank weight and cost. Fiberglass does not transmit as much light as glass or acrylic but can be translucent based on the type of resin used. Significant reinforcing of fiberglass walls can be provided with integral mesh fabrics incorporated in the walls and by external ribs. Resulting practical wall thickness is approximately 1 cm. Fiberglass is relatively non-reactive with chemicals and is less expensive than other materials.

Other construction approaches that were evaluated include fiberglass-covered wood construction, concrete block construction, and pre-cast concrete construction. Concrete block or pre-cast concrete tanks would be lined with high-density polyethylene liners to eliminate concerns regarding chemical reactivity between the water and the mesocosm. All these alternatives were rejected because of their opaque walls and their maintenance and/or construction cost.

3.2.2.2 Water Integrity

Small-scale mesocosms are easier to seal against unwanted leaks because construction materials tend to be watertight. Field-Scale PSTA mesocosms may have higher leakance because of their reliance on existing soils for embankment construction and bottom construction. Reduced water integrity in larger mesocosms results in more difficult water balance measurements and the ensuing uncertainty in mass balances. Leakance in full-scale

PSTAs from removal of organic substrates is a significant concern because of the potential for releases of dissolved P to downgradient waters.

Field-scale leakance requires one of two approaches: use of lined mesocosms (as in the PSTA Test Cells), or specific measurement (as in the Phase 2 Field-Scale PSTA cells).

3.2.2.3 Substrate Selection and Depth

Sediment interactions with overlying water and with emergent plants and algae are important factors for PSTA performance assessment. The type and amount of sediment to include in mesocosms is an important design issue. In addition to the importance of sediment chemistry, the physical structure and depth of the sediment is important for rooting and growth of emergent macrophytes that will be included in some PSTA mesocosms. David (1996) found that average substrate depths in WCA 3A in macrophyte stands, including *E. cellulosa*, *Rhyncospora tracyi*, and *Utricularia* spp., was between 43 and 48 cm.

There is concern that use of organic substrates typical of much of southeast Florida might result in rapid colonization of macrophytes that would shade periphyton (Kadlec and Walker, 1996; van der Valk and Crumpton, 1997). This process might lead to displacement of periphyton-dominated systems by emergent wetland macrophyte-dominated systems, resulting in P removal rates comparable to the STAs.

Two types of substrates are being evaluated for use in the experimental mesocosms: calcium-rich and organic. Calcium-rich substrates include a variety of materials grading from shellrock (recognizable marine mollusk fossils throughout) to limerock (few identifiable fossils present). The differing P sorption capacities of these materials and their incidence throughout the project area have not been investigated. Shellrock has been used to fill the ENR PSTA Test Cells and will be tested for use in the Porta-PSTAs.

Agricultural and wetland soils throughout the project area vary in composition based on their original depositional environment and subsequent use for agricultural activities. Organic soils typical of the ENR site are planned for use in the PSTA mesocosm studies. P sorption and de-sorption studies will be performed in the laboratory on all substrates used in the PSTA test systems.

3.2.2.4 Water Feed

Experimental mesocosms are typically operated on a batch basis or by continuous flow. Batch operation results in extreme temporal variation in water chemistry and resulting biological effects. Continuous flow operation results in more realistic successional patterns in biological community development, and allows assessment of spatial variability and varying loadings within a single mesocosm system.

A water feed system will be instrumented to allow measurement of hydraulic loadings to a mesocosm. Continuous measurements of inflow rate may be important if this rate is variable, but totalized flow measurements are adequate for many mesocosm applications.

3.2.2.5 Water Outflow and Depth Regulation

Water outflow rate must also be measured to assess mesocosm water balance. As with inflow rate, outflow rate measurements can be intermittent, continuous, or totalized over longer measurement intervals.

Water outflow structures can also be designed to allow water-depth control. Water depth in shallow wetland impoundments cannot be adequately controlled by bed slope or vegetation head loss (Kadlec and Knight, 1996). Design can allow continuous control of water levels or incremental water-depth settings.

3.2.2.6 Instrumentation/Monitoring Access

Monitoring access should be convenient and should have minimal impact on mesocosm operation and performance. Small-scale mesocosms can be designed to allow access by experimenters to any portion of the system. Larger, field-scale mesocosms may be inaccessible without specific monitoring structures, such as walkways and platforms that eliminate the potential for impacts to the community under study that might result from walking. Walkways and platforms must be small enough to minimize shading effects in the overall system and must be designed to allow the researcher to collect representative samples.

3.2.3 Mesocosm Operation

3.2.3.1 Hydraulic Loading and Hydraulic Residence Time

Hydraulic loading rate (q) defines the surface area (A) of a full-scale PSTA for a given water flow rate (Q) based on the relationship:

$$A = Q/q$$

HLR has been found to be highly correlated with performance of treatment wetlands (Kadlec and Knight 1996; Duke Wetland Center, 1997), and is presumed to be an important variable in PSTA design. HLR and nominal HRT are inversely proportional to depth (h) as indicated by:

$$q = h/HRT$$

This relationship assumes that porosity is high because of minimal volume occupied by plants in the PSTA mesocosms. The only way to test the effect of q on performance without changing HRT is to change depth at the same time. This has the undesirable effect of adding changes in surface:volume ratios between different treatments. Because q is considered *a priori* to be the key design criterion for the PSTA technology, this research will examine the effect of a range of HLRs.

In addition to experimental control of inflow q, the actual HRT distribution for the experimental systems will also be examined during Phase 1. This measurement is important to be able to develop the most appropriate model to simulate TP removal performance. Measurement of HRT includes estimation of the average HRT as well as the spread of residence times around that mean (Kadlec, 1994).

3.2.3.2 Feed Water Source

Feed water chemistry is expected to have a significant effect on PSTA performance. It is well documented that TP removal efficiency in Everglades wetlands is related to inflow TP concentration, typical of a first-order chemical reaction (Kadlec and Newman, 1992; Moustafa, 1993; Duke Wetland Center, 1997). PSTA mesocosm tests will be conducted for a variety of inflow TP concentrations that will bracket the range of natural variability typical of future STA discharges.

3.2.3.3 Periphyton Seeding and Macrophyte Planting

Mesocosms may need to be seeded and/or planted to establish periphyton and macrophyte communities within a reasonable study period. Based on a simple periphyton growth model, Kadlec and Walker (1996) estimated that initial seeding of well-developed periphyton mats (50 percent of steady-state biomass) could accelerate PSTA startup by up to 1 year. The experimental PSTA mesocosms and Test Cells will be seeded to "jumpstart" collection of research data. Seeding of the field-scale cells is currently planned on a limited basis.

Field-Scale PSTAs will receive constant seeding from upstream waters. Experimental systems must also have continuous access to a source of periphyton propagules. Inflow water for the Porta-PSTAs is expected to carry many of these microscopic propagules. This natural seeding has been observed in the shallow channels used for SAV/LR research.

Propagation of emergent macrophytes and their effect on PSTA performance are important research issues. Macrophytes can be effectively established in the mesocosms and in full-scale PSTAs by transplanting individual plants or rhizomes. Additional plant propagules will enter the PSTAs through the inlet water flow. Everglades macrophytes are known to be distributed in response to water regime and water column TP concentrations. David (1996) found typical Everglades slough macrophyte stands at average water depths to range from 33 to 37 cm in WCA 3A, and 25 to 28 cm in the Dupuis Reserve (David, unpublished). Average inundation frequencies at these sites were approximately 45 to 100 percent in WCA 3A, and 71 to 85 percent in the Dupuis Reserve.

Populations of *Utricularia* spp. and E. *cellulosa* were found to be limited to TP water concentrations less than 30 micrograms per liter (µg/L), while another common slough macrophyte, *Nymphea odorata,* had maximum plant cover at 50 µg TP/L (Duke Wetland Center, 1997). These results indicate that it may be challenging to obtain growth and propagation of these species at influent TP concentrations anticipated in a PSTA. Macrophytes are generally more dependent upon sediments than on the water column for growth nutrients, such as P. If PSTAs tend to accumulate P in their sediments, macrophyte growth may be better than in oligotrophic Everglades slough plant communities. There is considerable concern that undesirable colonization by macrophytes, such as cattails (*Typha* spp.) and sawgrass (*Cladium jamaicense*), may result in a need for plant eradication or periodic management (Kadlec and Walker, 1996; van der Valk and Crumpton, 1997). Experimental PSTA mesocosms at all 3 scales will be planted with desirable species, such as *Eleocharis* and *Utricularia*, but they will also be monitored for colonization and growth of other, competing macrophyte species.

3.2.3.4 Startup

Startup of new mesocosms requires time for shakedown and colonization. Shakedown consists of testing inflow and outflow adjustment and measurement, water-depth control, leak-testing, and methods development and testing. Colonization of periphyton communities to reach measurable population sizes may require several months at the slow growth rates typical of low TP waters. Monitoring during mesocosm startup will help to identify gross productivity rates as a function of community biomass and net biomass accretion rates. These growth rates are particularly important for evaluation of downtime that might result from periodic PSTA solids harvesting.

3.2.3.5 Sampling Methods and Materials

Sample collection and analysis is an expensive part of mesocosm research. Each additional station and sampling date adds considerable numbers of additional analyses, duplicates, data validation, and data analysis. While it is important to collect enough samples to be able to interpret results, collecting too many data can create problems with budgets, data entry, and analysis, and can paralyze completion of a research study.

Continuous data recording instruments are effective at providing details on experimental conditions. Reliance on such instrumentation is correlated with higher risk of data loss because of malfunctions and potential data quality issues if calibration drift occurs. An alternative to continuous data records is routine calibration and spot measurements using simpler (and less expensive) instruments.

3.2.3.6 Experiment Duration

The duration of most mesocosm experiments is dictated by practical considerations rather than scientific requirements. These experiments need to be conducted until mesocosm conditions approach realistic form and function, including a real or apparent steady-state for TP net accretion, or alternatively, until they begin to deviate from otherwise realistic behavior. Small, ecologically simple mesocosm experiments tend to lose species, and follow catastrophic successional courses. Larger systems tend to differentiate from each other along stochastic gradients, similar to the course of large natural environments. Larger systems tend to reach a quasi-steady-state at an ecological function level, while population composition may be very different between replicated systems.

The PSTA research project must be completed within a relatively short period of time, making it difficult to address directly all possible scale-up issues. It should be anticipated that follow-up studies will have to be conducted if this preliminary work proves that the concept is generally feasible and has promising initial net TP accretion rates. The PSTA performance forecast model will be the tool used during this preliminary research effort to project beyond the time frame of the study and to estimate performance and cost of this P-removal approach for a longer period.

3.2.3.7 Data Analysis

Powerful statistical analyses are not a good substitute for clearly separated operational treatments and controls. If it is not possible to see a significant difference between treatment means without statistics, that difference may have little use in the practical world. However, lack of readily understood statistical tests is sure to lead to doubt regarding data analysis

and interpretation. An appropriate application of statistical analyses during this technology demonstration will be needed. Candidate statistical analyses are detailed in Section 7.9.

3.3 Summary of PSTA Experimental Treatments

Based on input received from the Mesocosm Experience Workshop, the PSTA SRP, District scientists and engineers, and the data review and key experimental design issues described in this section, a limited number of priority treatments have been selected for testing during the PSTA research project. Key research priorities during Phase 1 and 2 are:

- Effect of calcium-rich versus organic substrate on TP accretion and colonization rate of macrophytes
- Effect of operational water depth on periphyton growth and TP accretion rate
- Effect of dry-down and variable water depth on TP accretion and system management

A number of ancillary issues related to PSTA performance and implementation will also be examined in demonstration Porta-PSTAs and by short-term experiments.

The detailed experimental design, including mesocosm dimensions, treatments, operation and sampling are presented in Sections 4, 5, and 6. Sampling and data analysis methods that are general to all of the experimental test systems are described in Section 7.

SECTION 4

ENR PSTA Test Cells

4.1 Site Layout

Three test cells within the South ENR Test Cell Site (Test Cells 3, 8, and 13) will be used for the PSTA demonstration program (Exhibit 4-1). These PSTA Test Cells have been modified by the District by placing additional layers of substrate over the sand surcharge layer as follows:

- Test Cell 3: 3.5 ft of sand surcharge plus 1.0 ft of shellrock (locally mined)
- Test Cell 8: 3.5 ft of sand surcharge plus 1.0 ft of shellrock (locally mined)
- Test Cell 13: 2.5 ft of sand surcharge plus 1.0 ft of shellrock (locally mined) plus 1 ft of peat (taken from the area of STA 1W, Cell 5 – unflooded, former agriculturally worked lands).

The final soil elevation in each PSTA Test Cell following the final grading was approximately equal.

4.2 ENR PSTA Test Cell Hydrologic Monitoring

Phase 1 start-up tests of the three ENR Test Cells will be performed to check hydrologic operations and replicability. These tests will include inflow control and monitoring and outflow monitoring. A tracer study will be conducted on each Test Cell using an inert compound (lithium chloride) to evaluate the initial hydraulic efficiency during Phase 1. These tracer tests will be repeated at the end of Phase 2 to determine how much hydraulic efficiency has changed as a result of periphyton and macrophyte colonization, during the 2-year study duration.

4.3 Experimental Treatments and Research Objectives

4.3.1 Phase 1

Experimentation in the ENR PSTA Test Cells will consist of the following 3 treatments during the study period from February 1999 to March 2000 (Phase 1):

- STC-1 (Test Cell 13): Organic substrate (peat soils), periphyton, and sparse macrophytes at 60 cm constant water depth
- STC-2 (Test Cell 8): Calcium-rich substrate (shellrock), periphyton, and sparse macrophytes at 60 cm constant water depth

Exhibit 4-1. Aerial View of Southern ENR Test Cells

- STC-3 (Test Cell 3): Calcium-rich substrate (shellrock), periphyton, and sparse macrophytes at variable water depth (0 to 60 cm) with periodic dry-down events

Exhibit 4-2 provides a summary of the experimental treatments to be examined in the ENR PSTA Test Cells during the Phase 1 study period. Detailed design criteria are summarized in Exhibit 4-3. A typical PSTA Test Cell layout is illustrated in Exhibit 4-4. These recommended design and operational conditions can be readily compared to similar tables in Sections 5 and 6 for the other experimental PSTA systems.

4.3.2 Phase 2

The following changes, summarized in Exhibit 4-2, will be made in the PSTA Test Cell treatments:

STC-4 (formerly STC-1)

- Beginning on March 7, 2000, this cell was drained and all macrophytes were killed with two herbicide applications and removed by hand. Soils were amended with lime (6.3 metric tonnes [mt]/ha), and the cell was replanted with spike rush and re-flooded to 30 cm depth on April 7, 2000. WCA-2A periphyton and bladderwort mix was added on April 12, 2000.
- Operation was re-started at approximately 6 cm/d HLR and the normal monitoring schedule was resumed on April 17, 2000. This Test Cell will be operated and monitored until February 14, 2001.

STC-5 (formerly STC-2)

- On January 13, 2000, the water depth was reduced to 30 cm with no other operational changes.
- Normal operation and monitoring schedule will be continued until February 14, 2001.

STC-6 (formerly STC-3)

- The water regime schedule was changed (see Exhibit 4-5) to allow complete dry-out and average water depth of 15 cm; two dry-outs with subsequent re-flooding are planned during 2000 (March 16 through May 10 and September 28 through November 23).
- Normal operation and monitoring schedule will be continued until February 14, 2001.

These Phase 2 PSTA research changes are expected to provide the following information:

- All 60 cm water depths have been converted to 30 cm or less to encourage improved periphyton growth and better contact between the surface water and the benthic periphyton mat.
- Amendment of peat soils in STC-4 with lime allows a large-scale test of the effect of this potentially cost-effective treatment on P retention and startup impacts.
- Changed water regime in STC-6 provides documentation of the effects of complete dryout/re-flooding twice during Phase 2.

Phase 2 Treatments				Phase 1 Treatments				
Phase 2 Treatment	Substrate	Water Depth (cm)	HLR (cm/d)	Phase 1 Treat-ment	Substrate	Water Depth (cm)	HLR (cm/d)	TC #
4	PE-CA	30	6	1	PE	60	6	13
5	SR	30	6	2	SR	60	6	8
6	SR	0-30	0-12	3	SR	0-60	0-12	3

PE = peat
PE-CA = peat amended with lime
SR = shellrock

Phase 2 Treatments				Phase 1 Treatments				
Phase 2 Treatment	Substrate	Water Depth (cm)	HLR (cm/d)	Phase 1 Treat-ment	Substrate	Water Depth (cm)	HLR (cm/d)	TC #
6	SR	0-30	0-12	3	SR	0-60	0-12	3
5	SR	30	6	2	SR	60	6	8
4	PE-CA	30	6	1	PE	60	6	13

Test Cell # - Phase 1/Phase 2 Treatments

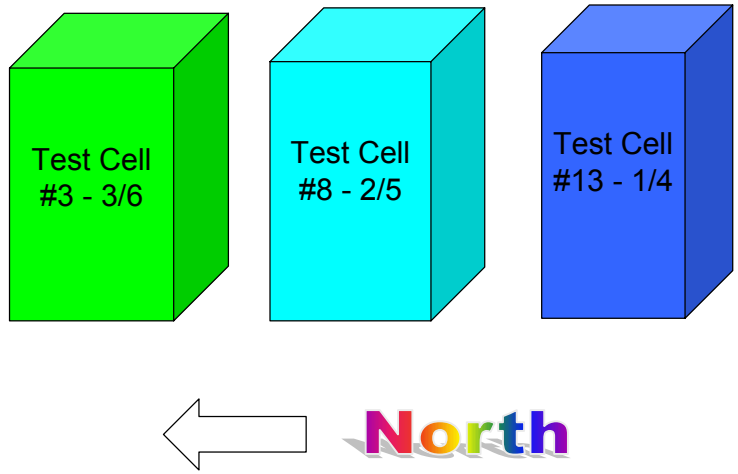


Exhibit 4-2. PSTA Test Cell Treatments for Phases 1 and 2

Exhibit 4-3

Detailed Design Criteria for ENR PSTA Test Cells

Design Parameter	Test Cell PSTA Treatment					
	1 STC-13	2 STC-8	3 STC-3	4 STC-13	5 STC-8	6 STC-3
No. Cells	1	1	1	1	1	1
Flow (m3/d)						
Average	134	134	134	134	134	134
Maximum	134	134	269	134	134	269
Minimum	134	134	1	134	134	1
Cell Length (m)	80	80	80	80	80	80
Cell Width (m)	28	28	28	28	28	28
Aspect Ratio	2.9	2.9	2.9	2.9	2.9	2.9
Horizontal Cell Area (m2)	2240	2240	2240	2240	2240	2240
Operational Water Depth (m)						
Average	0.60	0.60	0.30	0.30	0.30	0.15
Maximum	0.60	0.60	1.00	0.30	0.30	0.30
Minimum	0.60	0.60	0.01	0.30	0.30	0.00
Operational Water Volume (m3)						
Average	1344	1344	672	672	672	336
Maximum	1344	1344	2240	672	672	672
Minimum	1344	1344	22	672	672	0
Nominal Hydraulic Residence Time (d)						
@ average flow and depth	10.0	10.0	5.0	5.0	5.0	2.5
@ maximum flow and minimum depth	10.0	10.0	0.1	5.0	5.0	0.0
@minimum flow and maximum depth	10.0	10.0	2240.0	5.0	5.0	672.0
Hydraulic Loading Rate (cm/d)						
@ average flow and depth	6.0	6.0	6.0	6.0	6.0	6.0
@ maximum flow	6.0	6.0	12.0	6.0	6.0	12.0
@minimum flow	6.0	6.0	0.0	6.0	6.0	0.0
Nominal Linear Velocity (m/d)						
@ average flow and depth	8.00	8.00	16.00	16.00	16.00	32.00
@ maximum flow and minimum depth	8.0	8.0	960.0	16.0	16.0	
@minimum flow and maximum depth	8.00	8.00	0.04	16.00	16.00	0.12
Substrate	PE	SR	SR	PE-CA	SR	SR
Construction Material	Earth	Earth	Earth	Earth	Earth	Earth
Liner (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes
Deep Zones						
Number per Cell	0	0	0	0	0	0
Depth Below Floor Elevation (m)	NA	NA	NA	NA	NA	NA
Plant Species (Yes/No)						
Periphyton	Yes	Yes	Yes	Yes	Yes	Yes
Macrophytes	Yes	Yes	Yes	Yes	Yes	Yes
Design TP Influent Quality (ug/L)						
Average	25	25	25	25	25	25
Maximum	40	40	40	40	40	40
Minimum	15	15	15	15	15	15
Design TP Mass Loading (g/m2/y)						
Average	0.55	0.55	0.55	0.55	0.55	0.55
Maximum	0.88	0.88	0.88	0.88	0.88	0.88
Minimum	0.33	0.33	0.33	0.33	0.33	0.33

Notes:

m = meters

m^3/d = cubic meter(s) per day

m^2 = square meter(s)

cm/d = centimeter(s) per day

$g/m^2/y$ = grams(s) per square meter per year

µg/L = microgram(s) per liter

PE = peat

PE-CA = peat with lime

SR = shellrock

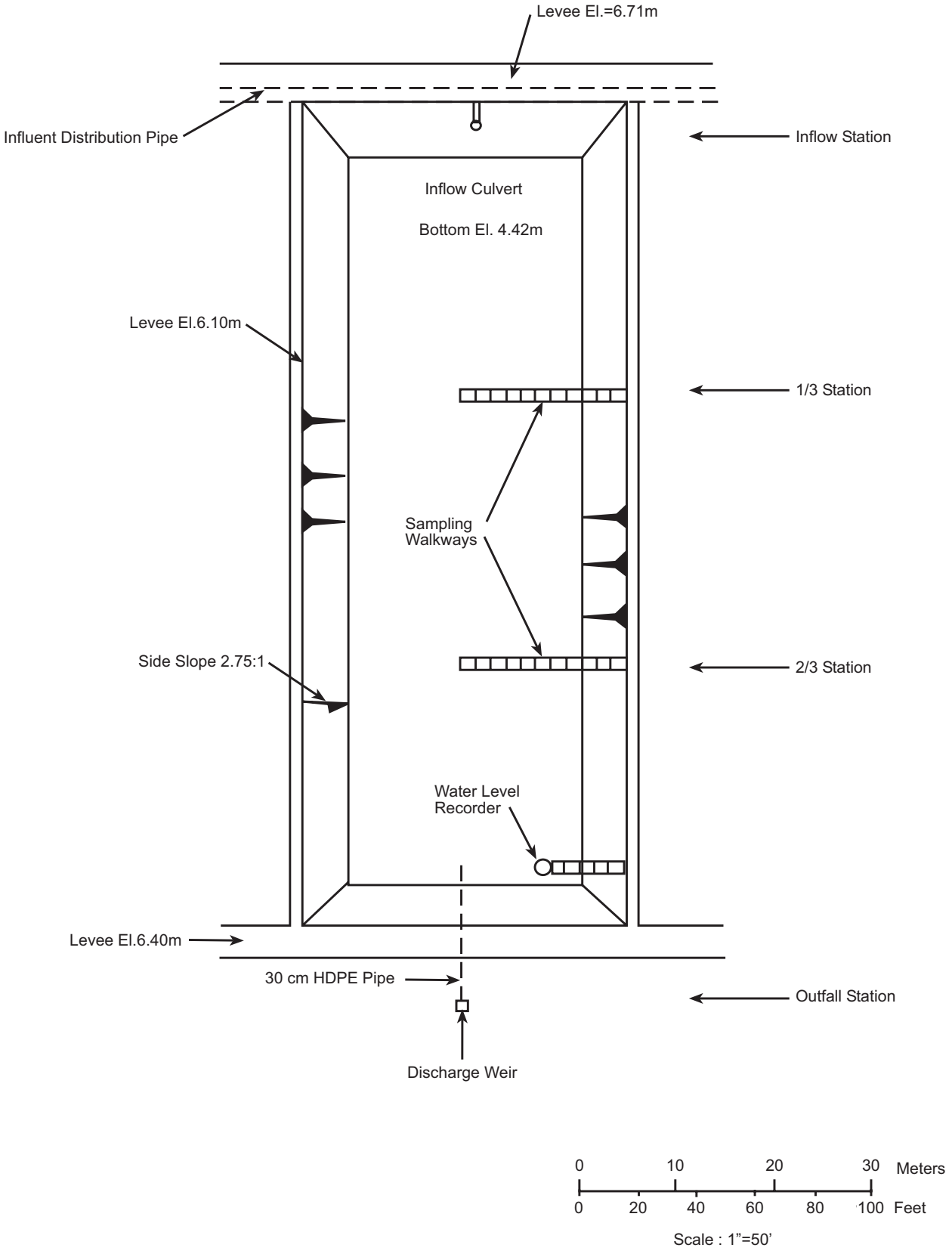


Exhibit 4.4. Plan View of Typical PSTA Test Cell Showing Sampling Locations.

- Continued operation of STC-5 with no operational changes other than depth decrease is important for interpretation of the effect of seasonality/succession upon original treatments for a 2-year operational period.

Phase 2 experimentation will primarily address dry-out effects, treatment performance during a second growing season and at more optimal depth conditions, and the effects of soil amendment on the rate of PSTA colonization and the system's treatment performance. In addition to tracking periphyton community development, macrophyte invasion will be observed and consideration will be given to control of proliferation if it jeopardizes the PSTA research studies. Monitoring of site conditions will be conducted on a routine weekly basis. Phase 2 experiments began in April 2000 and are currently planned to terminate in March 2001.

EXHIBIT 4-5
Planned Water Regime for ENR South Test Cell No. 3

Date	ENR South Test Cell 3 Orifice	ENR South Test Cell 3 Water Level
04/13/99	0.75 inch	15.3 feet
05/06/99	0.75 inch	15.8 feet
06/03/99	1.0 inch	17.1 feet
07/01/99	1.5 inch	17.1 feet
08/05/99	1.5 inch	17.1 feet
09/02/99	1.5 inch	16.8 feet
10/07/99	1.0 inch	16.6 feet
11/04/99	0.75 inch	16.0 feet
12/02/99	0.75 inch	15.3 feet
01/06/00	1.0 inch	14.8 feet
02/03/00	1.0 inch	14.7 feet
3/7/00	No flow	No flow
5/11/00	1.0 inch	15.5
6/8/00	1.5 inch	15.5
9/13/00	1.0 inch	15.0
9/28/00	No flow	No flow
11/23/00	0.75 inch	15.0
3/14/01	Finish Test Cell Phase 2 Study	

4.4 Monitoring Activities

The ENR PSTA Test Cells will be sampled quantitatively for multiple water quality and biological parameters (Exhibit 4-6). This exhibit reflects the sampling modifications made following the September 2000 SRP workshop. Station locations in a typical ENR PSTA Test Cell are illustrated in Exhibit 4-4. Temperature, pH, DO, and conductivity will be monitored continuously for the combined inflow to the three cells. These parameters will be measured weekly at the inflow and outflow of each cell, and monthly at the internal monitoring locations. Diel patterns for these parameters will be determined for each cell from hourly measurements using a multi-parameter sonde and a continuous data recorder. Instrumentation will be located internally at the two-thirds station and deployed for a 1-week period in each Test Cell before being rotated to another Test Cell. Photosynthetically

Exhibit 4-6

Phase 2 PSTA Test Cell Sampling Plan (November 2000 - March 2001) - SRP Workshop

		Sample Frequency				Number of Samples		
Parameter	Sampling Period (months)	Combined Inflow	Inflow	2/3	Outflow	Field	QC	Total
Field Sampling								
Flow	5	C(I)	W	NS	W	126	0	126
Water temperature	5	C(I)	W	M	W	141	0	141
Dissolved oxygen	5	C(I)	W	M	W	141	0	141
pH	5	C(I)	W	M	W	141	0	141
Conductivity	5	C(I)	W	M	W	141	0	141
PAR	5	NS	NS	M	NS	15	0	15
Water Quality Analyses								
Phosphorus (P) Series								
Total P	5	W	M	Q	W	102	20	122
Dissolved Reactive P	5	M	M	Q	M	38	8	46
Total Dissolved P	5	W	M	Q	W	102	20	122
Nitrogen (N) Series								
Total N	5	M	Q	Q	M	26	5	31
Ammonia N	5	M	Q	Q	M	26	5	31
Total kjeldahl N	5	M	Q	Q	M	26	5	31
Nitrate+nitrite N	5	M	Q	Q	M	26	5	31
Total organic carbon	5	M	Q	Q	M	26	5	31
Total suspended solids	5	M	Q	Q	M	26	5	31
Calcium	5	M	Q	Q	M	26	5	31
Alkalinity	5	M	Q	Q	M	26	5	31
Biological Analyses								
Periphyton Cover	5	NS		M		15	0	15
Macrophyte Cover	5	NS		M		15	0	15
Periphyton Dominant Species	5	NS	NS	Q	NS	3	0	3
Biomass (AFDW)	5	NS	NS	M	NS	15	3	18
Calcium	5	NS	NS	M	NS	15	3	18
Cholorophyll a, b,c, phaeophytin	5	NS	NS	M	NS	15	3	18
Phosphorus (P) Series								
Total P	5	NS	NS	M	NS	15	3	18
Total Inorganic P	5	NS	NS	M	NS	15	3	18
Non-reactive P	5	NS	NS	Q	NS	3	1	4
Total kjeldahl N	5	NS	NS	Q	NS	3	1	4
Sediments								
Phosphorus (P) Series								
Total P	5	NS	NS	E	NS	3	1	4
Total Inorganic P	5	NS	NS	E	NS	3	1	4
Non-reactive P	5	NS	NS	E	NS	3	1	4
Phosphorus Sorption/Desorption	5	NS		E		0	0	0
Total kjeldahl N	5	NS	NS	E	NS	3	1	4
Total organic carbon	5	NS	NS	E	NS	3	1	4
Bulk density	5	NS	NS	E	NS	3	1	4
Solids (percent)	5	NS	NS	E	NS	3	1	4
Accretion	5	NS	NS	Q	NS	3	0	3
System-Level Parameters								
Gross primary productivity	5	NS		Q		3	0	3
Net primary productivity	5	NS		Q		3	0	3
Community respiration	5	NS		Q		3	0	3
Standard of Comparison Sampling (Shifted Over From Field Scale)								
Sulfate	1	NS	5X	NS	5X	90	18	108
Dissolved ions/metals (Al, Fe, Ca, Mg, K, Si, Na, Cl)	0	NS	5X	NS	5X	90	18	108
Turbidity	0	NS	5X	NS	5X	90	18	108
Mercury (methylated)	0	NS	(D)	NS	(D)	60	12	72
Algal growth potential and chronic toxicity - *Selenastrum*	0	NS	5X	NS	5X	30	6	36
Chronic toxicity - *Cyprinella*	0	NS	5X	NS	5X	30	6	36
Chronic toxicity - *Ceriodaphnia*	0	NS	5X	NS	5X	30	6	36

Notes:

Assumes number of mesocosms = 3

W = weekly

M = monthly

Q = quarterly

A = annually

(D) = sampled by District

C(I) = continuous with instrument

NS = not sampled

na = not applicable

E = End of study phanse

Active Radiation (PAR) is recorded above the water surface continuously at the Advanced Treatment Technologies Research Area Porta-PSTA experimental site (see Section 5) and periodically with depth in the PSTA Test Cells using a submersible sensor to determine quality and quantity of light transmitted through the water column.

On a monthly basis, water samples collected from the combined inflow and cell outlets are analyzed for additional water quality constituents. These parameters are sampled on a quarterly basis at the inflow to each cell and the internal sampling stations. The analytes monitored monthly and quarterly are identified in Exhibit 4-6 and include the nitrogen (N) series, total suspended solids (TSS), calcium, and alkalinity.

In addition to water quality monitoring, the periphyton and macrophyte plant communities, sediment composition, and system-level parameters will be sampled monthly at one station within each Test Cell (at the two-third sample points). Periphyton and macrophyte plant cover will be visually estimated using percent cover categories and permanently documented with a photographic record. Water, periphyton, and sediment fractions will be analyzed for the parameters listed in Exhibit 4-6.

Periphyton community composition and P concentrations associated with the periphytic algal mat will be evaluated along a longitudinal gradient from the inflow to the outflow zones. This gradient will be accessed for sampling by simple walkways reaching from the side to the center of the cells at the one-third and two-thirds points along the length of each cell. These boardwalks have expanded base supports to prevent any damage to liner integrity. Water quality monitoring will focus primarily on inflow and outflow water quality measures, with less frequent collection of samples at the internal transect stations.

Accretion of new sediments will be measured at the end of the Phase 2 using horizon markers (feldspar) placed in each cell. Accretion rates will be measured at the one-third and two-third monitoring points.

During the course of Phase 2 monitoring activities, other analytical parameters called for in the "Standards of Comparison" (Peer consultants, Brown and Caldwell, 1998) and FDEP's Phase 1 screening protocol will be analyzed (FDEP, 1997). Parameters to be analyzed five times during Phase 2 are listed below. These samples will be collected during the course of routine monitoring of the sites listed above for two of the Test Cell PSTAs (shellrock and peat cells).

- Turbidity
- Sulfate
- Dissolved Magnesium
- Dissolved Potassium
- Dissolved Sodium
- Dissolved Iron
- Reactive Silica
- Dissolved Aluminum
- Color
- Total Dissolved Solids
- Dissolved Calcium
- Chloride
- Mercury (Methylated) (District)
- *Selanastrum* Tests: Algal Growth Potential (Nutrient Limiting) & Chronic Toxicity
- *Cyprinella* Tests: Chronic Toxicity
- *Ceriodaphnia Tests: Chronic Toxicity*

SECTION 5

Experimental-Scale Mesocosm (Porta-PSTA) Mesocosm Studies

5.1 Mesocosm Construction and Site Layout

Twenty-four Porta-PSTA mesocosm units will be fabricated offsite and delivered to the South ENR Supplemental Technologies Research Compound (STRC). The Porta-PSTA mesocosms are made of translucent fiberglass to minimize effects of shading by the walls. Experimental mesocosms are designed to be relatively portable, allowing them to be moved to an alternate location with a water supply with different P concentration.

Twenty-two tanks are 6 meters long by 1 meter wide by 1 meter deep. Two tanks are 3 meters wide to allow assessment of mesocosm configuration effects. The lower 20 cm of the walls and the tank bottoms is made with a gel-coat embedded into the fiberglass to make the material opaque. Tanks are arranged in parallel directly on the existing shellrock base, and are oriented with their long axes on a north-south line to minimize wall shading effects during maximum insolation periods. Each mesocosm is spaced approximately 0.6 meters (2.0 ft) apart to allow researchers access to the entire system, resulting in dimensions for the array of approximately 6 x 39 meters, not counting the head tank and inlet/outlet plumbing.

A single 0.5 m^3 (264-gallon) opaque head tank receives input water from the existing pipeline, and provides a constant head to the valves regulating flow into the 24 mesocosms.

This head tank has sufficient water volume to run the 24 mesocosms at average flow rate for up to 2 hours if there is a pump failure or need for pump maintenance. The head tank has an overflow that allows maintenance of a constant head. An outlet is provided in the center bottom of the head tank and feeds two 5-cm (2-inch) diameter horizontal manifold pipes located near the upstream end of the 2 mesocosm arrays. Valves are located at each Porta-PSTA inlet and are used to regulate flow of water from the manifold through individual fittings located for each mesocosm.

Perforated flow baffles are provided approximately 15 cm (6 inches [in]) from the upstream end of each mesocosm. These baffles have 1-cm-diameter holes drilled 10 cm on center to help distribute water over the entire cross-sectional area of the inlet. A floating skimmer is located approximately 15 cm upstream of the downstream end of each mesocosm to trap floating algae, plants, and particulates within the mesocosm. This baffle extends from slightly above the water line to approximately 10 cm below the water line. Water input is in front of the first baffle, and multiple water overflow ports are located downstream of the final baffle. Water overflow points in the mesocosms are located at water depths of -5, 10, 30, 60, and 70 cm above the level of the substrate. Outflow and water depth are controlled by selection between multiple overflow weirs.

Substrate in the Porta-PSTAs consists of 20 cm of either peat (organic soil from the ENR site), shellrock, or beach sand. Multiple soil layers, such as those in ENR PSTA South Test Cell 13, are not used in the Porta-PSTAs to eliminate possible confusion during interactions between these substrate types.

Macrophytes and periphyton will be established in the Porta-PSTAs prior to startup. Macrophytes (*E. cellulosa* and *Utricularia* spp.) will be planted from nursery or field-harvested stock. *Eleocharis* will be planted at a density of 2 to 3 plant clumps (approximately 11 live shoots total) per m^2. Approximately 4 liters of live *Utricularia* and associated periphyton will also be introduced to each mesocosm following startup of water flows.

A section view of a Porta-PSTA tank is provided in Exhibit 5-1. Exhibit 5-2 provides a plan view of the Porta-PSTA experimental setup showing the layout of typical 1- and 3-meter wide mesocosms in relation to the constant-head tank and inlet manifolds. Detailed design and operational criteria are summarized in Exhibit 5-3.

5.2 Experimental Treatments and Research Objectives

5.2.1 Phase 1

A total of 24 Porta-PSTAs are deployed at the South ENR STRC. During Phase 1, six different priority experimental treatments will be replicated three times for a total of 18 mesocosms. The priority experimental treatments for Phase 1 will include:

- Substrate type (peat vs. shellrock)
- Water depth (60 or 30 cm average depth)
- HLD (6 or 12 cm/d)
- Variable water regime (0 to 60 cm variable water depth with variable HLR)

One set of three shellrock mesocosms (Treatment 6) will receive variable inflows and has variable water depth to simulate seasonally varied scale PSTA operation.

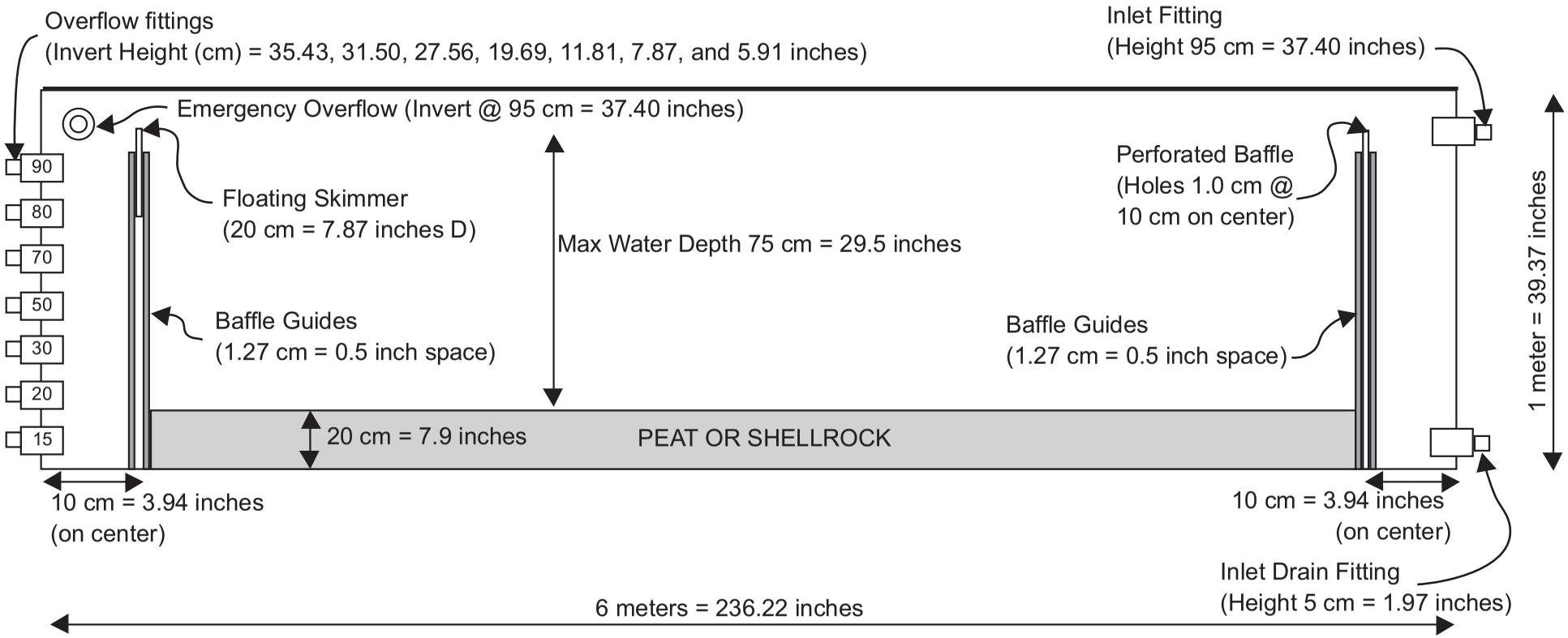
Six additional unreplicated treatments will be used to demonstrate PSTA performance in treatment configurations that may be less optimal than those covered in the replicated mesocosms. The un-replicated Phase 1 treatments will include:

- Two Porta-PSTAs with sand soils to act as substrate controls
- A test of the effect of excluding all plants from both shellrock- and peat-based Porta-PSTAs using Aquashade dye (plantless controls)
- Two Porta-PSTAs that vary in depth:width ratio while holding other variables constant to assess the effects of walls and their surface area:volume effect on Porta-PSTAs performance

Phase 1 experimental treatments are summarized in Exhibit 5-4 and will be conducted for the study period of April 1999 to March 2000 (Phase 1).

Water depths in nine of the replicated cells will be maintained at 60 cm, and the average HLR will be held constant at either 6 or 12 cm/d (250 or 500 milliliters per minute [mL/min]

TANK DIMENSIONS: 22 @ 6m L x 1m W x 1m D; 2 @ 6m L x 3m W x 1m D



SECTION VIEW

Note: Not to Scale

Exhibit 5-1. Porta-PSTA Section View

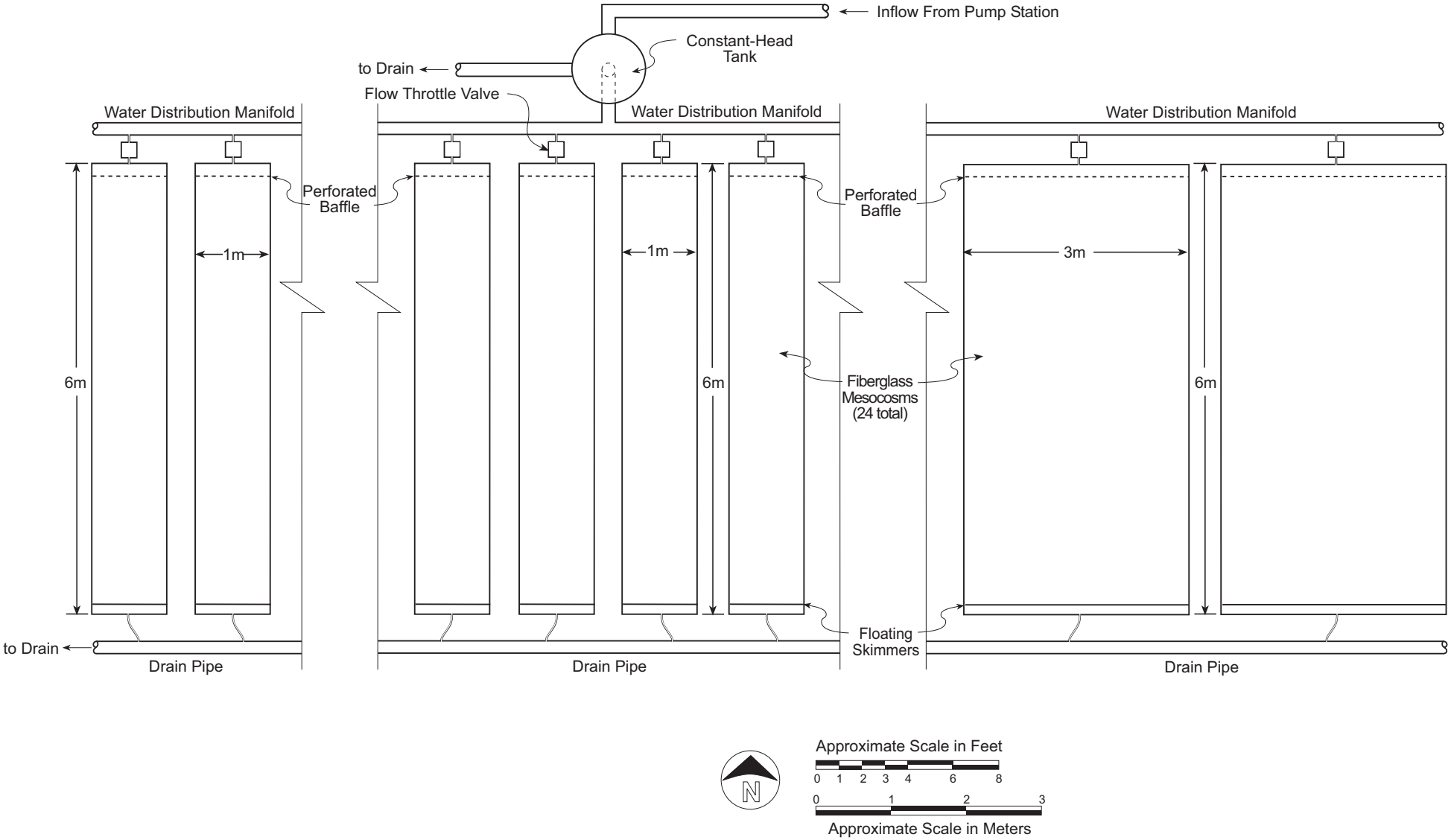


Exhibit 5-2. Porta-PSTA Experimental Mesocosm Site Plan

Exhibit 5-3

Design Criteria for Porta-PSTA Experimental Treatments

Design Parameter	Porta-PSTA Treatment																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
No. Cells	3	3	3	3	3	3	1	1	1	1	1	1	3	3	3	3	1	1	1
Flow (m3/d)																			
Average	0.36	0.36	0.36	0.36	0.72	0.36	0.36	0.36	0.36	0.36	1.08	1.08	0.36	0.36	0.36	0.15	0.36	0.36	0.36
Maximum	0.36	0.36	0.36	0.36	0.72	0.72	0.36	0.36	0.36	0.36	1.08	1.08	0.36	0.36	0.36	0.37	0.36	0.36	0.36
Minimum	0.36	0.36	0.36	0.36	0.72	0.05	0.36	0.36	0.36	0.36	1.08	1.08	0.36	0.36	0.36	0.00	0.36	0.36	0.36
Flow (mL/min)																			
Average	250	250	250	250	500	250	250	250	250	250	750	750	250	250	250	104	250	250	250
Maximum	250	250	250	250	500	500	250	250	250	250	750	750	250	250	250	257	250	250	250
Minimum	250	250	250	250	500	35	250	250	250	250	750	750	250	250	250	0	250	250	250
Recirculation Flow (m3/d)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0	0	0	0
Cell Depth (m)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Cell Length (m)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Cell Width (m)	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	3.00	3.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Length:Width Ratio	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	2.0	2.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
Water Depth:Width Ratio	0.6	0.6	0.3	0.3	0.6	0.3	0.3	0.6	0.6	0.6	0.1	0.1	0.3	0.3	0.3	0.2	0.3	0.3	0.3
Area (m2)																			
Horizontal surface area	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	18.00	18.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Wall Area (@ design depth)	8.40	8.40	4.20	4.20	8.40	4.20	4.20	8.40	8.40	8.40	5.40	5.40	4.20	4.20	4.20	2.10	4.20	4.20	4.20
Operational Water Depth (m)																			
Average	0.60	0.60	0.30	0.30	0.60	0.30	0.30	0.60	0.60	0.60	0.30	0.30	0.30	0.30	0.30	0.15	0.30	0.30	0.30
Maximum	0.60	0.60	0.30	0.30	0.60	0.60	0.30	0.60	0.60	0.60	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Minimum	0.60	0.60	0.30	0.30	0.60	0.01	0.30	0.60	0.60	0.60	0.30	0.30	0.30	0.30	0.30	0.00	0.30	0.30	0.30
Operational Water Volume (m3)																			
Average	3.60	3.60	1.80	1.80	3.60	1.80	1.80	3.60	3.60	3.60	5.40	5.40	1.80	1.80	1.80	0.90	1.80	1.80	1.80
Maximum	3.60	3.60	1.80	1.80	3.60	3.60	1.80	3.60	3.60	3.60	5.40	5.40	1.80	1.80	1.80	1.80	1.80	1.80	1.80
Minimum	3.60	3.60	1.80	1.80	3.60	0.06	1.80	3.60	3.60	3.60	5.40	5.40	1.80	1.80	1.80	0.00	1.80	1.80	1.80
Nominal Hydraulic Residence Time (d)																			
@ average flow and depth	10.00	10.00	5.00	5.00	5.00	5.00	5.00	10.00	10.00	10.00	5.00	5.00	5.00	5.00	5.00	6.00	5.00	5.00	5.00
@ maximum flow and minimum depth	10.00	10.00	5.00	5.00	5.00	0.08	5.00	10.00	10.00	10.00	5.00	5.00	5.00	5.00	5.00	0.00	5.00	5.00	5.00
@minimum flow and maximum depth	10.00	10.00	5.00	5.00	5.00	72.00	5.00	10.00	10.00	10.00	5.00	5.00	5.00	5.00	5.00	INF	5.00	5.00	5.00
Hydraulic Loading Rate (cm/d)																			
@ average flow and depth	6.0	6.0	6.0	6.0	12.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	2.5	6.0	6.0	6.0
@ maximum flow	6.0	6.0	6.0	6.0	12.0	12.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.2	6.0	6.0	6.0
@ minimum flow	6.0	6.0	6.0	6.0	12.0	0.8	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	0.0	6.0	6.0	6.0
Nominal Linear Velocity (m/d)																			
@ average flow and depth	0.60	0.60	1.20	1.20	1.20	1.20	1.20	0.60	0.60	0.60	1.20	1.20	1.20	1.20	433.20	1.00	1.20	1.20	1.20
@ maximum flow and minimum depth	0.60	0.60	1.20	1.20	1.20	1.20	1.20	0.60	0.60	0.60	1.20	1.20	1.20	1.20	433.20	1.23	1.20	1.20	1.20
@ minimum flow and maximum depth	0.60	0.60	1.20	1.20	1.20	5.00	1.20	0.60	0.60	0.60	1.20	1.20	1.20	1.20	433.20	0.00	1.20	1.20	1.20
Substrate Depth (m)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Substrate Type	PE	SR	PE	SR	SR	SR	SA	SA	PE	SR	SR	PE	PE-CA	LR	SR	SR	SA-R	NS	NS
Construction Material	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG	FG
Liner (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Freeboard (m)																			
@ average depth	0.10	0.10	0.40	0.40	0.10	0.40	0.40	0.10	0.10	0.10	0.40	0.40	0.40	0.40	0.40	0.55	0.40	0.40	0.40
Plant Species (Yes/No)																			
Periphyton	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Macrophytes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
None (Aquashade Control)	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No
Aquamat (synthetic)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes
Design TP Influent Quality (ug/L)																			
Average	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Maximum	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40
Minimum	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Design TP Mass Loading (g/m2/y)																			
Average	0.55	0.55	0.55	0.55	1.10	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.23	0.55	0.55	0.55
Maximum	0.88	0.88	0.88	0.88	1.75	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.37	0.88	0.88	0.88
Minimum	0.33	0.33	0.33	0.33	0.66	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.14	0.33	0.33	0.33

Notes:
m = meters
mL/min= milliliter(s) per minute
m^3/d = cubic meter(s) per day
m^2 = square meter(s)
cm/d = centimeter(s) per day
$g/m^2/y$ = grams(s) per square meter per year
µg/L = microgram(s) per liter
PE = peat
PE-CA = peat with lime
SR = shellrock
LR = limerock
SA = sand
SA-R = sand rinsed with HCl
NS = no substrate
INF = infinite
FG = fiberglass

Phase 2 Treatments					Phase 1 Treatments						
Phase 2 Treatment	Substrate	Water Depth (cm)	Velocity (cm/s)	HLR (cm/d)	Phase 1 Treatment	Sub-strate	Aqua-shade	Water Depth (cm)	HLR (cm/d)	Width (m)	PP Tank #
13a	PE-CA	30	0.0014	6	1a	PE	no	60	6	1	9
13b	PE-CA	30	0.0014	6	1b	PE	no	60	6	1	11
13c	PE-CA	30	0.0014	6	1c	PE	no	60	6	1	18
14a	LR	30	0.0014	6	2a	SR	no	60	6	1	7
14b	LR	30	0.0014	6	2b	SR	no	60	6	1	4
14c	LR	30	0.0014	6	2c	SR	no	60	6	1	8
3a	PE	30	0.0014	6	3a	PE	no	30	6	1	17
3b	PE	30	0.0014	6	3b	PE	no	30	6	1	14
3c	PE	30	0.0014	6	3c	PE	no	30	6	1	12
4a	SR	30	0.0014	6	4a	SR	no	30	6	1	10
4b	SR	30	0.0014	6	4b	SR	no	30	6	1	5
4c	SR	30	0.0014	6	4c	SR	no	30	6	1	3
15a	SR	30	0.5000	6	5a	SR	no	60	12	1	16
15b	SR	30	0.5000	6	5b	SR	no	60	12	1	2
15c	SR	30	0.5000	6	5c	SR	no	60	12	1	13
16a	SR	0-30	0.0014	6	6a	SR	no	0-60	6	1	6
16b	SR	0-30	0.0014	6	6b	SR	no	0-60	6	1	15
16c	SR	0-30	0.0014	6	6c	SR	no	0-60	6	1	1
7	SA	30	0.0014	6	7	SA	no	60	6	1	19
17	SA-R	30	0.0014	6	8	SA	no	60	6	1	20
18	NS	30	0.0014	6	9	PE	yes	60	6	1	21
19	SY	30	0.0014	6	10	SR	yes	60	6	1	22
11	SR	30	0.0014	6	11	SR	no	30	6	3	23
12	PE	30	0.0014	6	12	PE	no	30	6	3	24

PE = peat
PE-CA = peat amended with lime
LR = limerock

SR = shellrock
SA = sand
SA-R = HCl-rinsed sand

NS = no substrate
SY = synthetic

Phase 2 Treatments					Phase 1 Treatments						
Phase 2 Treatment	Substrate	Water Depth (cm)	Velocity (cm/s)	HLR (cm/d)	Phase 1 Treatment	Sub-strate	Aqua-shade	Water Depth (cm)	HLR (cm/d)	Width (m)	PP Tank #
16c	SR	0-30	0.0014	6	6c	SR	no	0-60	6	1	1
15b	SR	30	0.5000	6	5b	SR	no	60	12	1	2
4c	SR	30	0.0014	6	4c	SR	no	30	6	1	3
14b	LR	30	0.0014	6	2b	SR	no	60	6	1	4
4b	SR	30	0.0014	6	4b	SR	no	30	6	1	5
16a	SR	0-30	0.0014	6	6a	SR	no	0-60	6	1	6
14a	LR	30	0.0014	6	2a	SR	no	60	6	1	7
14c	LR	30	0.0014	6	2c	SR	no	60	6	1	8
13a	PE-CA	30	0.0014	6	1a	PE	no	60	6	1	9
4a	SR	30	0.0014	6	4a	SR	no	30	6	1	10
13b	PE-CA	30	0.0014	6	1b	PE	no	60	6	1	11
3c	PE	30	0.0014	6	3c	PE	no	30	6	1	12
15c	SR	30	0.5000	6	5c	SR	no	60	12	1	13
3b	PE	30	0.0014	6	3b	PE	no	30	6	1	14
16b	SR	0-30	0.0014	6	6b	SR	no	0-60	6	1	15
15a	SR	30	0.5000	6	5a	SR	no	60	12	1	16
3a	PE	30	0.0014	6	3a	PE	no	30	6	1	17
13c	PE-CA	30	0.0014	6	1c	PE	no	60	6	1	18
7	SA	30	0.0014	6	7	SA	no	60	6	1	19
17	SA-R	30	0.0014	6	8	SA	no	60	6	1	20
18	NS	30	0.0014	6	9	PE	yes	60	6	1	21
19	SY	30	0.0014	6	10	SR	yes	60	6	1	22
11	SR	30	0.0014	6	11	SR	no	30	6	3	23
12	PE	30	0.0014	6	12	PE	no	30	6	3	24

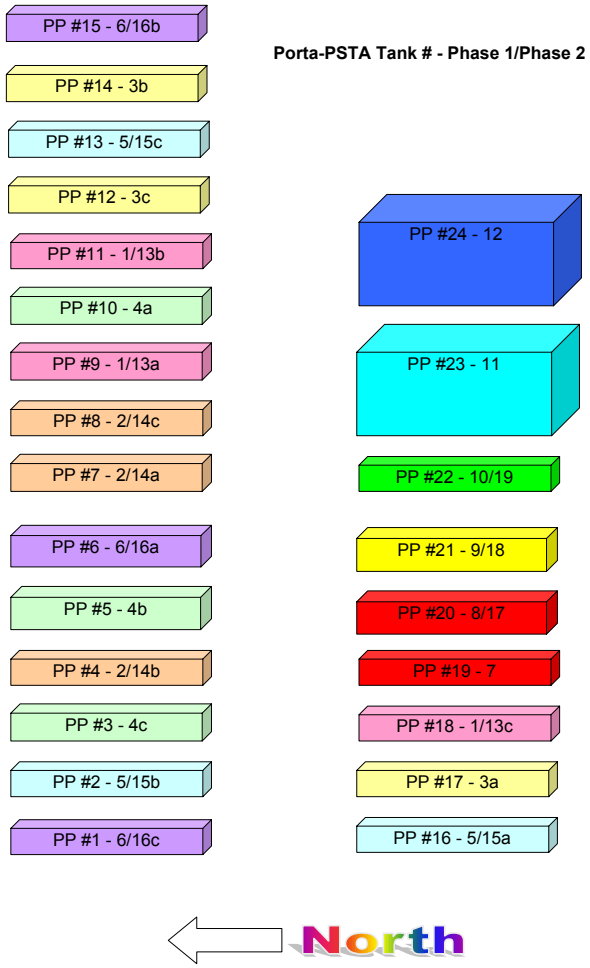


Exhibit 5-4. Porta-PSTA Treatments for Phase 1 and 2

CH2M HILL

to each cell). The 6 cm/d HLR assumes an average P removal rate constant of 35 m/y to reduce total P from approximately 30 µg/L to 10 µg/L. Higher effective average HLRs will also be periodically simulated (quarterly) by internal sampling at the one-third (18 cm/d) and two-third points in each cell (9 cm/d).

5.2.2 Phase 2

Several possible constraints for the PSTA concept were identified during Phase 1. These include the following:

- Phase 1 data analysis indicated that the PSTA design used in this research (peat, shellrock, or sand soils) was not able to achieve monthly average TP outflow concentrations of less than 9 µg/L within the first year of operation. The lowest monthly treatment averages were 11 µg/L on shellrock soils and 12 µg/L on peat soils.
- Emergent macrophyte density overwhelms periphyton dominance on peat soils. Macrophyte colonization rate is probably dependent upon antecedent soil conditions, nutrient content, and seedbank composition.
- Variable water inflow rates and levels resulted in lower TP removal performance and higher outflow TP concentrations at the Test Cell mesocosm scale.
- Presence of uncontrolled grazer populations (snails) leads to higher TP outflow concentrations and reduced mass removals.

The Phase 2 research and demonstration plan has been developed to address some of these issues and to replicate the best mesocosm results at the field-scale. Some of the existing PSTA mesocosm treatments are being continued for varying lengths of time to fully document the annual cycle of PSTA performance after the initial 4 to 5 months of startup. New treatments will be added to investigate:

- Whether peat soils can be used with a higher level of management, such as the use of chemical amendments and herbicide applications.
- Whether limerock holds greater promise than shellrock for the lowest achievable TP outflow concentrations and highest periphyton colonization rates.
- Whether higher flow velocities provide a subsidy or a stress in terms of increased P removal rates and periphyton TP export.
- The effects of complete dryout and re-wetting on PSTA performance at the Test Cell research scale.

Based on the results of Phase 1 and comments from the Scientific Review Panel meeting in December 1999, a number of changes were made to the Phase 2 PSTA research in the Porta-PSTA treatments. These changes are summarized in Exhibit 5-4 and are described below:

PP-1. On March 16, 2000, PP-1 was converted to PP-13 (see next page)

PP-2. On March 16, 2000, PP-2 was converted to PP-14 (see next page)

PP-3. Continue routine monitoring schedule with no changes until September 30, 2000

PP-4. Continue routine monitoring schedule with no changes until September 30, 2000

PP-5. On March 16, 2000, PP-5 was converted to PP-15 (see next page)

PP-6. On March 16, 2000, PP-6 was converted to PP-16 (see below)

PP-7. Continue routine monitoring schedule with no changes until September 30, 2000

PP-8. On March 16, 2000, PP-8 was converted to PP-17 (see below)

PP-9. On March 16, 2000, PP-9 was converted to PP-18 (see below)

PP-10. On March 16, 2000, PP-10 was converted to PP-19 (see below)

PP-11. Continue routine monitoring schedule with no changes until September 30, 2000

PP-12. Continue routine monitoring schedule with no changes until September 30, 2000

PP-13. (formerly PP-1)

- Beginning on March 16, 2000, drain tanks and harvest spikerush for re-planting; herbicide remaining macrophytic plants; amend peat with lime (6.3 mt/ha); replant with spikerush; re-flood to 30 cm depth; add WCA-2A periphyton and bladderwort mix
- Re-start operation at approximately 6 cm/d HLR
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

PP-14 (formerly PP-2)

- On March 16, 2000, drain tanks and harvest spikerush for re-planting; remove shellrock and rinse tanks with dilute HCl and water; fill with 20 cm of washed limerock; replant and re-flood to 30 cm; add WCA-2A periphyton and bladderwort mix
- Re-start operation at approximately 6 cm/d HLR
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

PP-15 (formerly PP-5)

- Beginning on March 16, 2000, reduce HLR to approximately 6 cm/d and lower depth to 30 cm
- Install re-circulation pumps (1.5 liters per second [L/s] [24 gpm]) to maintain internal velocity at approximately 0.5 cm/d
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

PP-16 (formerly PP-6)

- On March 16, 2000, begin new water regime with water depth fluctuation between 0 and 30 cm and HLR between 0 and 12 cm/d; flow off from March 6 until May 11, 2000; flow on at 320 mL/min (7.7 cm/d) from May 11 until June 8, 2000; flow at 500 mL/min (12 cm/d) from June 8 until September 2000
- Continue routine monitoring schedule until September 2000

PP-17 (formerly PP-8)

- Beginning on March 16, 2000, drain tank and harvest spikerush for re-planting; thoroughly wash sand with dilute HCl to remove available P; drain and rinse tank with water; replant and re-flood to 30 cm; add WCA-2A periphyton and bladderwort mix
- Re-start operation at approximately 6 cm/d HLR
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

PP-18 (formerly PP-9)

- Beginning on March 16, 2000, drain tank to remove Aquashade; remove all substrate; rinse tank with dilute HCl and water; re-flood to 30 cm; add WCA-2A periphyton and bladderwort mix
- Re-start operation at approximately 6 cm/d HLR
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

PP-19 (formerly PP-10)

- Beginning on March 16, 2000, drain tank to remove Aquashade; remove all substrate; rinse tank with dilute HCl and water; re-flood to 30 cm; add synthetic substrate (e.g., Aquamat^{TM}); add WCA-2A periphyton only
- Re-start operation at approximately 6 cm/d HLR
- On April 17, 2000, resume normal monitoring schedule until September 30, 2000

These Phase 2 treatment changes were made to provide the following information:

- All 60 cm water depths were converted to 30 cm or less to encourage improved periphyton growth and better contact between the water and the benthic periphyton.
- Continued operation of PP-3, PP-4, PP-7, PP-11, and PP-12 with no operational changes provides a continuous 18-month operational period (12-month post startup period) with all soil types and at both depth:width ratios. These data are important for interpretation of the effect of seasonality/succession upon the original treatments.
- Converting PP-5 (new PP-15) to high recycle (0.5 cm/s velocity) with operation at 6 cm/d allows replicated quantification of this important full-scale design parameter on performance.
- Changed water regime in PP-6 (new PP-16) allows measurement of effects of complete dryout/re-flooding.
- Amending peat soils with lime in PP-1 (new PP-13) provides replicated quantification of this relatively low-cost fix on TP removal rates and background outflow concentrations.
- Replacing shellrock with limerock in PP-2 (new PP-14) allows a replicated test of the effect of this promising PSTA substrate as observed in SAV raceway experiments (DBEL, 1999).

- Washing sand in PP-8 (new PP-17) with dilute HCl provides a better test of having a soil with no available dissolved reactive phosphorus (DRP) bleed-back.
- Establishing a tank with no soil but with periphyton (formerly PP-9, new PP-18) provides a better test of the effect of soil on total phosphorus (TP) bleed-back.
- Establishing a tank with no soil and with inert substrate but no macrophytes (formerly PP-10, new PP-19) allows a test of biologically inert substrate for periphyton growth.

5.3 Monitoring Activities

Porta-PSTA mesocosm monitoring includes collection of multiple water quality and biological parameters. A detailed description of specific monitoring parameters and frequencies for Phase 2, as revised following the September 2000 SRP workshop, is provided in Exhibit 5-5.

Inflow is expected to be constant to each cell and is calibrated twice per week by collection of a timed volume of water at the inflow point. Outflow from each cell is measured weekly by collection of a timed volume of water at the cell overflow tube.

Temperature, pH, DO, and conductivity are monitored continuously for the combined inflow at the head tank. These parameters are measured weekly at the inflow and outflow of each cell, and monthly at the center point. Diel patterns for these parameters are determined for each cell from continuous measurements taken at mid-depth at the center of each tank using a multi-parameter sonde and a continuous data recorder for a 3-day period once per month. PAR is recorded monthly with depth in each mesocosm using a submersible sensor to determine quality and quantity of light transmitted through the water column, and to detect effects of wall shading.

Water quality monitoring focuses on inflow and outflow water quality measures, with less frequent collection of samples from the center of the tanks at mid-depth. TP, DRP, and total dissolved phosphorus (TDP) are sampled weekly at the head tank and at the outlet from each of the 24 mesocosms. On a monthly basis, a single grab sample from each of the cell inlets is collected and analyzed for these same P forms. The P series is also measured quarterly at the center of the tank and at mid-depth.

On a monthly basis, a single head tank inflow sample and outflow water samples from each mesocosm are analyzed for additional water quality constituents. These parameters are sampled quarterly at the cell inlets and at the single internal sampling station in each Porta-PSTA. The analytes that are monitored monthly and quarterly are identified in Exhibit 5-5 and include the nitrogen series, TSS, calcium, and alkalinity.

In addition to the water quality monitoring, the periphyton community and sediment composition, and system-level parameters are sampled monthly or quarterly at one station within mesocosm. Periphyton and macrophyte plant cover is visually estimated using percent cover categories and supported with a photographic record. Fractionated samples of surface water, periphyton, and sediment components are analyzed for the parameters listed in Exhibit 5-5. In terms of community characterization, periphyton samples are analyzed for species composition, density, chlorophyll and phaeophytin, and community biomass.

Internal sample "fields" are used to randomize destructive sampling for periphyton and sediments. A sampling grid is used with randomly selected sample locations to allow precision sampling without repetition at any single location during the study period. This grid excludes the bottom area of the mesocosms within 10 cm of the side walls to eliminate the potential problem of wall effects on periphyton growth and TP accretion in the sediments.

Accretion of new sediments will be measured at the end of the Phase 2 monitoring using a horizon marker in each mesocosm. Samples will be collected at the inflow and outflow monitoring points.

At the culmination of these studies, selected Porta-PSTA mesocosms will be destructively sampled as outlined in Appendix D.

Exhibit 5-5
Phase 2 PSTA Porta-PSTA Sampling Plan (April 2000 - October 2000)

		Sample Frequency				Number of Samples		
Parameter	Sampling Period (years)	Combined Inflow	Inflow	1/2	Outflow	Field	QC	Total
Field Sampling								
Flow	0.5	NS	C(I)	NS	W	624	0	624
Water temperature	0.5	C(I)	W	M	W	1392	0	1392
Dissolved oxygen	0.5	C(I)	W	M	W	1392	0	1392
pH	0.5	C(I)	W	M	W	1392	0	1392
Conductivity	0.5	C(I)	W	M	W	1392	0	1392
PAR	0.5	NS	NS	M	NS	144	0	144
Water Quality Analyses								
Phosphorus (P) Series								
Total P	0.5	W	M	Q	W	842	168	1010
Dissolved Reactive P	0.5	W	M	Q	M	362	72	434
Total Dissolved P	0.5	W	M	Q	W	842	168	1010
Nitrogen (N) Series								
Total N	0.5	M	Q	Q	M	246	49	295
Ammonia N	0.5	M	Q	Q	Q	150	30	180
Total kjeldahl N	0.5	M	Q	Q	M	246	49	295
Nitrate+nitrite N	0.5	M	Q	Q	M	246	49	295
Total organic carbon	0.5	M	Q	Q	M	246	49	295
Total suspended solids	0.5	M	Q	Q	M	246	49	295
Calcium	0.5	M	Q	Q	M	246	49	295
Alkalinity	0.5	M	Q	Q	M	246	49	295
Biological Analyses								
Periphyton Cover	0.5	NS		M		144	0	144
Macrophyte Stem Count	0.5	NS		M		144	0	144
Periphyton Dominant Species	0.5	NS		M		144	0	144
Biomass (AFDW)	0.5	NS		M		144	29	173
Calcium	0.5	NS		M		144	29	173
Chlorophyll a, b,c, phaeophytin	0.5	NS		M		144	29	173
Phosphorus (P) Series								
Total P	0.5	NS		M		144	29	173
Total Inorganic P	0.5	NS		M		144	29	173
Non-reactive P	0.5	NS		Q		24	5	29
Total kjeldahl N	0.5	NS		Q		48	10	58
Sediments								
Phosphorus (P) Series								
Total P	0.5	NS		M		144	29	173
Total Inorganic P	0.5	NS		M		144	29	173
Non-reactive P	0.5	NS		Q		24	5	29
Phosphorus Sorption/Desorption	0.5	NS		A		12	0	12
Total kjeldahl N	0.5	NS		Q		48	10	58
Total organic carbon	0.5	NS		Q		48	10	58
Bulk density	0.5	NS		M		144	29	173
Solids (percent)	0.5	NS		M		144	29	173
Accretion	0.5	NS		A		12	0	12
System-Level Parameters								
Gross primary productivity	0.5	NS		Q		48	0	48
Net primary productivity	0.5	NS		Q		48	0	48
Community respiration	0.5	NS		Q		48	0	48
Totals						**12342**	**1081**	**13423**

Notes:

Assumes number of mesocosms = 24

W = weekly
M = monthly
Q = quarterly
A = annually

(D) = sampled by District
C(I) = continuous with instrument
NS = not sampled

SECTION 6

Field-Scale Mesocosm Experiments

6.1 Field Scale Design

Planning has been underway to develop a Field-Scale PSTA testing and demonstration system since the PSTA project startup in August 1998. The original proposed site for the Field-Scale PSTA research was located in the STA-3/4 footprint west of U.S. 27 and just north of WCA-3A. Site-specific studies and scheduling constraints with District leases determined that a better location for the Field-Scale PSTA project would be just west of STA-2 and east of the North New River and U.S. 27.

The Field-Scale PSTA facilities were designed by the District, with technical input from the CH2M HILL PSTA team. The original design includes three 5-acre cells. During the SRP workshop in September 2000, discussions concluded that it would be advantageous to have a fourth, peat-based cell. The site design has been revised, and the final design includes a total wetted Field-Scale PSTA area of approximately 20 acres divided into four 5-acre PSTA cells. Exhibit 6-1 provides a plan view of the Field–Scale PSTA facility. Construction is expected to be completed by February 2001 and operation will start soon after. Cell 4 construction is being funded by a cooperative agreement between the District and the National Park Service. Operations are expected to start in March 2001.

As illustrated in Exhibits 6-1 and 6-2, the four Field-Scale PSTAs have differing design criteria. These design criteria are summarized as follows:

- **Cell 1:** 5 acres with a length:width ratio of 5:1 (length = 1,040 ft, width = 200 ft); limerock fill over peat soils; single inlet and outlet points in transverse deep water zones; inlet pumping capacity of approximately 450 gpm; outlet variable height weir with flow by gravity; embankments 4.5 ft above grade with 2:1 (horizontal:vertical) limerock slopes; planted with bands of low density of spike rush.
- **Cell 2:** 5 acres with a length:width ratio of 45:1 (length = 3,120 ft, width = 70 ft); limerock fill over peat soils; single inlet and outlet points in transverse deep water zones; additional transverse deep zones at 1/3 and 2/3 points inlet pumping capacity of 450 gpm; outlet variable height weir with flow by gravity; embankments 4.5 ft above grade with 2:1 limerock slopes; planted with bands of low density of spike rush.
- **Cell 3:** 5 acres with a length:width ratio of 5:1 (length = 1,040 ft, width = 200 ft); peat soils excavated to caprock; single inlet and outlet points in transverse deep water zones; inlet pumping capacity of 450 gpm; outlet variable height weir with flow pumped up to 1,000 gpm; embankments 4.5 ft above grade with 2:1 limerock slopes; planted with bands of low density of spike rush.
- **Cell 4:** 5 acres with a length:width ratio of 5:1 (length = 1,040 ft, width = 200 ft); peat soils; single inlet and outlet points in transverse deep water zones; inlet pumping capacity of

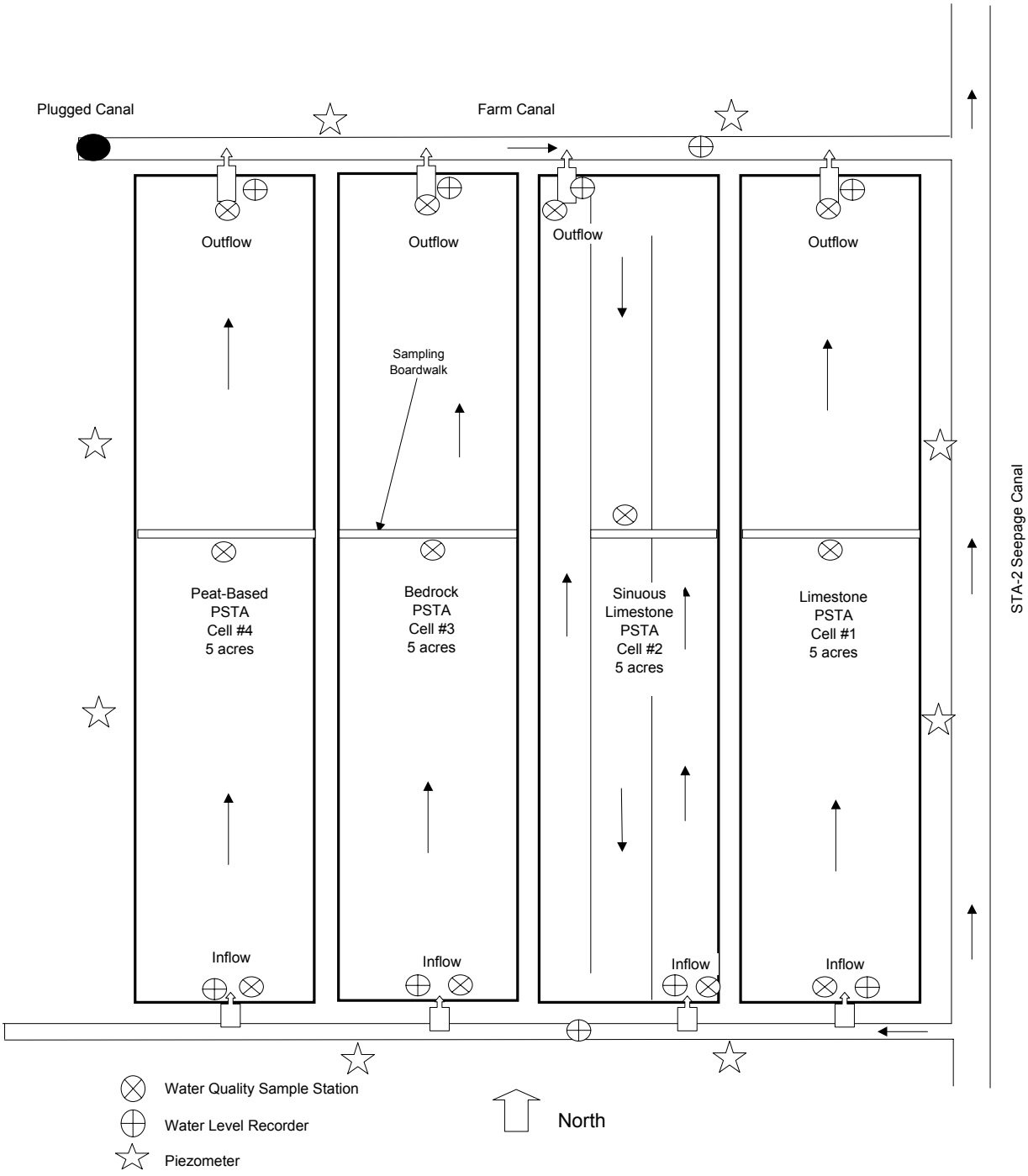


Exhibit 6-1
Schematic of Field Scale Cells Showing Sampling Locations

Exhibit 6-2

Detailed Design Criteria for Field Scale PSTA Cells

Design Parameter	Field-Scale PSTA Treatment 1	2	3	4
No. Cells	1	1	1	1
Flow (m3/d)				
Average	1250	1250	1250	1250
Maximum	2500	2500	2500	2500
Minimum	0	0	0	0
Cell Length (m)	315	945	315	315
Cell Width (m)	66	22	66	66
Aspect Ratio	5	43	5	5
Horizontal Cell Area (m2)	20790	20790	20790	20790
Operational Water Depth (m)				
Average	0.30	0.30	0.30	0.30
Maximum	0.60	0.60	0.60	0.60
Minimum	0.00	0.00	0.00	0.00
Operational Water Volume (m3)				
Average	6237	6237	6237	6237
Maximum	12474	12474	12474	12474
Minimum	0	0	0	0
Nominal Hydraulic Residence Time (d)				
@ average flow and depth	5.0	5.0	5.0	5.0
@ maximum flow and minimum depth	0.0	0.0	0.0	0.0
@minimum flow and maximum depth	INF	INF	INF	INF
Hydraulic Loading Rate (cm/d)				
@ average flow and depth	6.0	6.0	6.0	6.0
@ maximum flow	12.0	12.0	12.0	12.0
@minimum flow	0.0	0.0	0.0	0.0
Nominal Linear Velocity (m/d)				
@ average flow and depth	63	189	63	63
Substrate	LR-PE	LR-PE	CR	PE
Liner (Yes/No)	No	No	No	No
Deep Zones				
Number per Cell	2	4	2	2
Depth Below Floor Elevation (m)	1	1	1	1
Plant Species (Yes/No)				
Periphyton	Yes	Yes	Yes	Yes
Macrophytes	Yes	Yes	Yes	Yes
Design TP Influent Quality (ug/L)				
Average	25	25	25	25
Maximum	40	40	40	40
Minimum	15	15	15	15
Design TP Mass Loading (g/m2/y)				
Average	0.55	0.55	0.55	0.55
Maximum	0.88	0.88	0.88	0.88
Minimum	0.33	0.33	0.33	0.33

Notes:

m = meters

m^3/d = cubic meter(s) per day

m^2 = square meter(s)

cm/d = centimeter(s) per day

$g/m^2/y$ = grams(s) per square meter per year

µg/L = microgram(s) per liter

INF = infinite

PE = peat

LR-PE = limerock fill over peat

CR = limestone caprock

- approximately 450 gpm; outlet variable height weir with flow by gravity; embankments 4.5 ft above grade with 2:1 (horizontal:vertical) limerock slopes; planted with bands of low density of spike rush.

Cell 1 is bordered on the east by the west STA-2 seepage control canal that serves as the primary intended source of water for the PSTA cells. An alternative water supply is to convey STA-2, Cell 3 waters directly to the Field Scale site inflow canal. Infrastructure for this water supply option is being put in place to provide operational flexibility during, and beyond, Phase 2.

Lateral canals along the south and north sides of the PSTA cells provide the water supply and outlet, respectively. Seepage control canals are also included between Cells 2 and 3 and between Cells 3 and 4 to control seepage between these cells with widely different water stages.

6.2 Hydrogeologic Site Testing

Overall water balance estimates will be an important aspect of research at the Field-Scale PSTA site. These tests and analyses will be performed to help address the concerns regarding full-scale system constructability.

The Field-Scale PSTA hydrologic monitoring plan has been prepared outlining the number and location of shallow monitor wells to be installed around the Field-Scale PSTA mesocosm study area. Monitor wells will be installed to a depth of approximately 3.0 to 4.6 m (10 to 15 ft) below ground surface. The well screen is expected to be below the cap rock. The wells will be 5-cm (2-inch)-diameter PVC with 1.5 m (5 ft) of slotted screen. The wells will be installed with a sand pack around the screen, and the annulus grouted to ground surface.

Soil borings will be conducted along with the installation of the monitor wells. The thickness of the peat and cap rock layers at each location will be noted. In addition, *in situ* samples of the peat will be collected at five locations. The peat samples will be collected using a Shelby tube and sent to a laboratory for permeability testing. At three of the infiltrometer locations, samples of the muck (peat) will be collected, compacted to a density similar to that of a berm constructed of muck, and sent to a laboratory for permeability testing. The permeability results will be used to estimate horizontal seepage through a muck dike.

Seepage and permeability testing will consist of double-ring infiltrometer tests, slug tests, and a pumping test. The double-ring infiltrometer tests will be conducted at locations that approximate the locations of the monitor wells. The infiltrometer tests will be conducted at each location with the peat layer in place, then tested again with the peat removed. Test results will be used to estimate the vertical hydraulic conductivity at each location.

Slug tests and a pumping test will also be performed to estimate the horizontal hydraulic conductivity at the site. Slug tests will be performed at each monitor well. One pumping test will be conducted using a central monitor well as the pumped well, and up to four of the surrounding wells for observation.

6.3 Monitoring Activities

Exhibit 6-3 presents a summary of the proposed Field-Scale PSTA research sampling plan based on input received at the September 2000 SRP workshop. This exhibit is presented in the same format as the sampling plans for the Porta-PSTAs and Test Cells presented in Sections 4 and 5. All of the methods proposed for the Field-Scale PSTA monitoring are the same as those currently being used in the other PSTA mesocosm research, with two exceptions:

- Water stage is monitored by use of Infinity continuous water level recorders (i.e., RDS WL-40 or equivalent).
- Internal samples for water and periphyton will be composited along the entire width of each cell at the mid-point from a single boardwalk

Proposed sampling frequency for many of the parameters listed in Exhibit 6-3 is greater than in the current research at the Porta-PSTAs and Test Cells. This greater proposed frequency is warranted based on the scale of this portion of the demonstration project. These experiments cannot be as easily re-run as those at the smaller scale, and the detailed findings from the Field-Scale PSTAs are needed for development of full-scale design criteria development.

Exhibit 6-1 provides a schematic plan view of the proposed Phase 2 facility with proposed monitoring locations. Structures to facilitate monitoring access and ease were included in the final design (i.e., all-weather roads, trails, and walkways).

Start-up of the Field-Scale PSTA mesocosms will consist of a series of tests to check hydrologic operation. These tests will include inflow control and monitoring, outflow monitoring and a tracer study will be performed to quantify HRT and mixing characteristics.

A key issue to be examined with the Field-Scale PSTA mesocosms during Phase 2 will be quantification of groundwater and TP losses as a function of cell size. Field-Scale PSTA hydrologic tests will be conducted for each cell sediment configuration during this project by temporarily interrupting surface inflows and outflows, and continuously measuring water level changes in response to infiltration and evapotranspiration. The relative contribution of vertical seepage and bank seepage to total water losses will be determined, if possible, or calculated using literature-supported methods. P content of infiltrating groundwater will be assessed through sampling of piezometers installed at strategically important locations near the Field-Scale PSTA mesocosms.

Ground P and chloride concentrations around the perimeter of the Field-Scale PSTA study area will be monitored monthly during Phase 2. Groundwater quality monitoring will focus on establishing water and P mass budgets for these mesocosms. PAR and other measures will be made using appropriate meters. Relevant field measures (temperature, pH, DO, conductivity, color, turbidity) will be made at each station at the time of water sample collections.

Exhibit 6-3
Phase 2 Field Scale Pilot PSTA Monitoring Plan - SRP Workshop
(Monitoring to be conducted for Cells 1, 2, 3, & 4 for an 8 month period, November 2000 - June 2001)

		Sampling Locations and Frequency						Number of Samples		
Parameter	Sampling Period (months)	Piezometers	Inflow Canal	Inflow	1/2	Outflow	Outflow Canal	Field	QC	Total
Field Meter Readings										
Flow	8	na	na	Pump	na	calc	na	na	na	na
Water Stage	8	W	C(I)	W	W	C(I)	C(I)	na	na	na
Water temperature	8	W	W	W	W	C(I)	na	1092	0	1092
Dissolved oxygen	8	na	W	W	W	C(I)	na	1092	0	1092
pH	8	W	W	W	W	C(I)	na	1092	0	1092
Conductivity	8	W	W	W	W	C(I)	na	1092	0	1092
Total Dissolved Solids (note a)	8	W	W	W	W	C(I)	na	1092	0	1092
Turbidity (note a)	8	W	W	W	W	C(I)	na	1092	0	1092
PAR	8	na	na	na	M	na	na	32	0	32
Water Quality Analyses										
Phosphorus (P) Series										
Total P	8	M	NS	W	M	W	NS	827	165	992
Dissolved Reactive P	8	NS	NS	W	M	W	NS	549	110	659
Total Dissolved P	8	NS	NS	W	M	W	NS	549	110	659
Nitrogen (N) Series	8									
Total N	8	NS	NS	M	Q	M	NS	96	19	115
Ammonia N	8	NS	NS	M	Q	M	NS	96	19	115
Total kjeldahl N	8	NS	NS	M	Q	M	NS	96	19	115
Nitrate+nitrite N	8	NS	NS	M	Q	M	NS	96	19	115
Total suspended solids	8	NS	NS	M	Q	M	NS	96	19	115
Total organic carbon	8	NS	NS	M	Q	M	NS	96	19	115
Calcium	8	NS	NS	M	Q	M	NS	96	19	115
Alkalinity	8	NS	NS	M	Q	M	NS	96	19	115
Chlorides	8	M	NS	M	Q	M	NS	240	48	288
Biological Analyses										
Periphyton Cover	8	NS	NS	NS	M	NS	NS	32	0	32
Macrophyte Cover	8	NS	NS	NS	M	NS	NS	32	0	32
Periphyton Dominant Species	8	NS	NS	NS	Q	NS	NS	32	0	32
Biomass (AFDW)	8	NS	NS	NS	M	NS	NS	128	26	154
Calcium	8	NS	NS	NS	M	NS	NS	128	26	154
Cholorophyll a, b,c, phaeophytin	8	NS	NS	NS	M	NS	NS	128	26	154
Phosphorus (P) Series										
Total P	8	NS	NS	NS	M	NS	NS	128	26	154
Total Inorganic P	8	NS	NS	NS	M	NS	NS	128	26	154
Non-reactive P	8	NS	NS	NS	Q	NS	NS	43	9	51
Total kjeldahl N	8	NS	NS	NS	Q	NS	NS	43	9	51
Accretion (Net Organic/Inorganic)	8	NS	NS	NS	Q	NS	NS	128	26	154
Sediments (Start and End)										
Phosphorus (P) Series										
Total P	8	NS	NS	NS	S/E	NS	NS	112	22	134
Total Inorganic P	8	NS	NS	NS	S/E	NS	NS	112	22	134
Non-reactive P	8	NS	NS	NS	S/E	NS	NS	112	22	134
Phosphorus Sorption/Desorption	8	NS	NS		S/E		NS	112	22	134
Total kjeldahl N	8	NS	NS	NS	S/E	NS	NS	112	22	134
Total organic carbon	8	NS	NS	NS	S/E	NS	NS	112	22	134
Bulk density	8	NS	NS	NS	S/E	NS	NS	112	22	134
Solids (percent)	8	NS	NS	NS	S/E	NS	NS	112	22	134
System-Level Parameters										
Gross primary productivity	8	NS	NS		C(I)		NS	32	0	32
Net primary productivity	8	NS	NS		C(I)		NS	32	0	32
Community respiration	8	NS	NS		C(I)		NS	32	0	32
								11459	**937**	**12395**

Notes:

note a = presumes Hydrolab sensor available
W = weekly
M = monthly
Q = quarterly
(D) = sampled by District
C(I) = continuous with instrument
NS = not sampled
S/E - start and end of study phase
na = not applicable
Assumes number of piezometers = 12
Assumes number of mesocosms = 4

SECTION 7

Sample Collection and Data Analysis

CH2M HILL has prepared and submitted a Quality Assurance Project Plan (QAPP) to FDEP for review. The QAPP details sampling procedures, analytical methods, and QC samples planned for the PSTA research project. In response to FDEP, a revised QAPP was prepared for Phase 2 and is provided as Appendix A. This section provides a preliminary overview of the material that is addressed in greater detail in the formal QAPP. Detailed Standard Operating Procedures (SOPs) for site maintenance, operation, and sample collection are provided in Appendix C.

7.1 Quality Assurance/Quality Control

Laboratory personnel follow procedures outlined in the laboratory's Comprehensive Quality Assurance Plan (CompQAP) for sample kit preparation, tracking and analysis of samples, and data validation. CH2M HILL field personnel follow procedures outlined in CH2M HILL's CompQAP for the execution of field activities, proper completion of chain-of-custody forms, sample preservation requirements, and proper handling of samples. Strict adherence of holding times for all parameters is observed.

Field meters are calibrated by the field team in accordance with the manufacturer's recommendations, and are consistent with standard procedures outlined in CH2M HILL's CompQAP. Calibration results are recorded in the field notebook.

During each sampling event, the following field quality assurance/quality control (QA/QC) samples are collected as follows:

- Duplicate samples at a rate of 10 percent of total samples
- Equipment blanks at a rate of 5 percent of total samples

7.2 Meteorological Measurements

The District maintains a number of weather stations throughout the ENR and at S7 for the Field-Scale project vicinity. Data from these installations is used to the greatest extent possible to fill the information needs described in this section.

7.2.1 Incoming Solar Radiation

Total insolation is measured at the south ENR advanced treatment technology site and at the Field-Scale site. Insolation is recorded continuously over the period of all mesocosm experiments.

PAR is measured continuously using special sensors above the water surface, and periodically with depth in each mesocosm. Periodic measurements are taken in representative mesocosms to determine the variation in total PAR and light extinction as a function of water depth, side-to-side variation, and longitudinal variation. A light extinction coefficient is calculated for each mesocosm for all sampling events.

7.2.2 Precipitation

The District ENR project records precipitation in the vicinity of the ENR project. These data are used for the ENR PSTA Test Cell and Porta-PSTA water balances. A continuous recording rain gauge will be installed at the Field-Scale site.

7.2.3 Pan Evaporation

The District ENR project records pan evaporation in the vicinity of the ENR project. These data will be used for the ENR PSTA Test Cell and Porta-PSTA water balances. A pan evaporation station will be installed at the Field-Scale site. As a preliminary assumption, PSTA evapotranspiration will be estimated as 0.77 times pan evaporation. No attempt will be made to provide a more detailed estimate of evapotranspiration in the PSTA mesocosms.

7.2.4 Air Temperature

The District ENR project records air temperature in the vicinity of the ENR project. These data will be used for the ENR PSTA Test Cell and Porta-PSTA water balances. A continuous recording thermometer will be installed at the Field-Scale site.

7.3 Physical Measurements

7.3.1 Water Depth

Staff gauges will be installed in all mesocosms to provide a convenient means of measuring water depth during routine field visits. Water level recorders will be installed in the three ENR PSTA Test Cells by the District. Infinity data loggers will be installed in the four Field-Scale PSTA mesocosms to provide a continuous record of water levels during operation.

7.3.2 Water Temperature

Submersible thermistors are used to record temperature in each mesocosm on a rotating basis.

7.3.3 Water Flow Rates

7.3.3.1 ENR Test Cells

Inflows to the PSTA Test Cells will be estimated based on head cell stage and inlet orifice diameter using rating curves developed by the District. Head cell water stage will be recorded every 0.5 hours and reported by the District. PSTA Test Cell outflows will be estimated by water height over 90-degree v-notch weirs. Water stage will be measured intermittently using staff gauges and will be continuously recorded by water level recorders in each cell by the District.

7.3.3.2 Porta-PSTAs

Inflow rates to the Porta-PSTAs will be routinely checked for accuracy (at least twice per week) by measuring the time required to fill a sample container with known volume. Outflow rates from the Porta-PSTAs will be measured by use of a graduated cylinder and a stop-watch at least weekly from all Porta-PSTA mesocosms.

7.3.3.3 Field-Scale Mesocosms

Inflow to the Field-Scale PSTA mesocosms will be measured with a totalizer located at the inlet to each cell. These instruments will be calibrated according to manufacturer specifications. Outflow from the Field-Scale PSTA mesocosms will be measured by continuous records of water levels and use of the horizontal weir equation for water flowing over the outlet stoplogs.

7.4 Water Quality Measurements

PSTA water samples are collected at a variety of sample points and with different methods. Some samples are collected from inflow and outflow lines, others are collected as grab samples below the water surface, and others are collected by use of compositing samplers. This section briefly describes the water quality analyses that are routinely made during the PSTA Research and Demonstration Project. Parameters and sampling frequencies are outlined in Exhibits 4-6 (Test Cells), 5-5 (Porta-PSTAs), and 6-3 (Field Scale Cells).

7.4.1 Field Parameters

7.4.1.1 DO

DO is routinely measured in the PSTA mesocosms using a Hydrolab Minisonde Multiprobe. Diel DO profiles are measured with the same instrument outfitted with a data logger for continuous operation.

7.4.1.2 Hydrogen Ion

Hydrogen ion (pH) is measured with a Hydrolab Minisonde Multiprobe. Diel pH profiles are measured with a recording instrument intended for continuous operation.

7.4.1.3 Specific Conductance

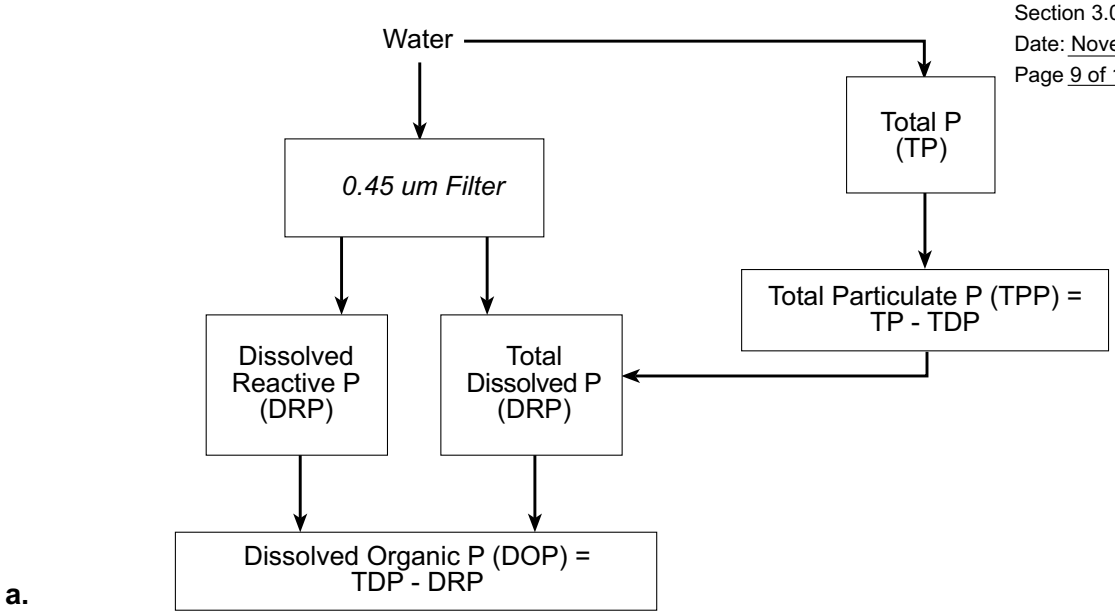
Specific conductance is measured by use of a Hydrolab Minisonde Multiprobe Diel conductivity profiles are measured with a recording instrument intended for continuous operation.

7.4.2 Laboratory Parameters

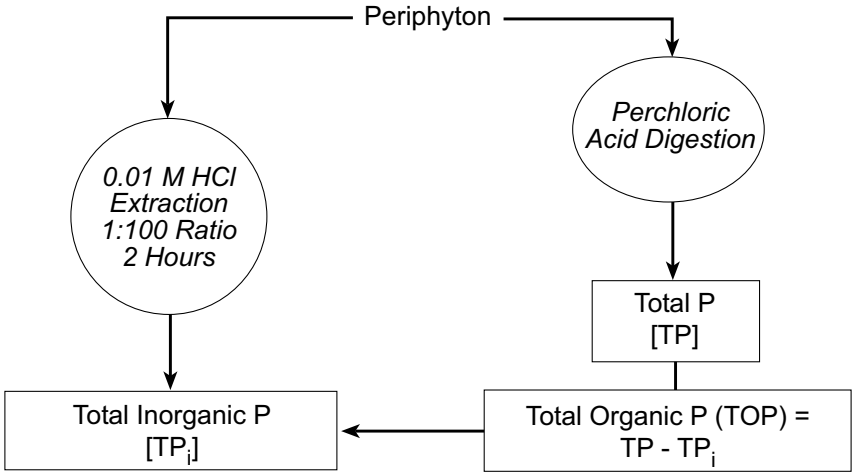
Water samples are routinely collected from the mesocosms for analysis of P and N forms, total organic carbon (TOC), TSS, calcium, and alkalinity. Most samples planned are grab samples; however, some composited samples will be collected to evaluate differences between instantaneous and integrated samples. For the Field-Scale pilot PSTAs, composites of outflows will be used for P analyses.

7.4.2.1 P Speciation

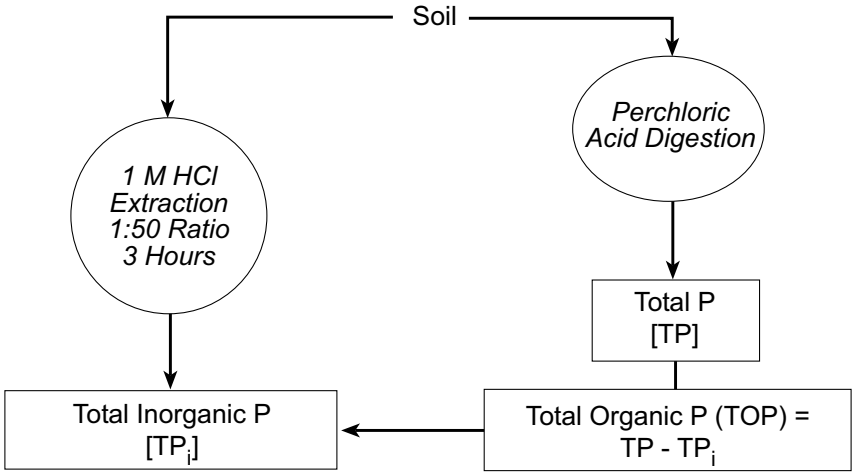
Exhibit 7-1a illustrates the analytical procedures that are used to speciate the various forms of P in water samples for the PSTA project. Water samples are collected in clean sample containers in the field, with 250 mL being filtered through a 0.45 micrometer (μm) filter for measurement of TDP and DRP. TP and TDP fractions are acidified with ultra-pure sulfuric acid. The two filtrate samples are digested (standard persulfate digestion) in the laboratory to estimate TDP, and directly measured without digestion for DRP. The unfiltered sample



a.



b.



c.

Exhibit 7-1. Routine Phosphorus Fractionation Methods for a. Water Samples, b. Perphyton Samples, and c. Sediment Samples.

is digested (persulfate digestion) with perchloric acid and analyzed for TP. The difference between TP and TDP is equal to total particulate P (TPP). The difference between TDP and DRP is equal to dissolved organic P (DOP). This method does not specifically distinguish between organic and inorganic particulate P. Additional analyses are conducted on a selected subset of samples to learn more about the ratio of these fractions.

7.4.2.2 Nitrogen Series

Surface water nitrogen (N) concentrations are determined at a reduced schedule compared to P. However, a basic understanding of the availability of this plant growth nutrient is essential for PSTA process understanding. The full N series is analyzed to allow calculation of total nitrogen (TN). These analyses include: total kjeldahl nitrogen (TKN) (organic + ammonia N), total ammonia N (inorganic reduced N), and nitrate + nitrite N (inorganic oxidized N). Organic N is equal to the difference between TKN and total ammonia N. TN is equal to the sum of TKN and nitrate + nitrite N.

7.4.2.3 TOC

TOC is measured to provide additional information on carbon transfer into and out of the experimental mesocosms.

7.4.2.4 TSS

TSS is a method that integrates most of the particulates in the water column. Because P is easily transported in a particulate form, TSS provides an important confirmatory estimate of the particulate TP fraction that is entering and exiting the mesocosms.

7.4.2.5 Calcium and Alkalinity

Co-precipitation of P with calcium carbonate is hypothesized to be an important process in PSTA TP retention. Calcium availability is directly measured as total calcium, while carbonate alkalinity is measured to document the amount of dissolved inorganic carbon available for this chemical precipitation pathway.

7.5 Sediment Analyses

Sediment samples are collected using plastic coring tubes (approximately 5 cm inside diameter) driven by hand into sediments or by directly filling sample containers. Roots and rhizomes are analyzed as part of the sediments. Sediment cores are typically collected from the 0 to 10 cm interval.

7.5.1 P Sorption/Desorption Isoltherms

P sorption and desorption are measured on the limerock, shellrock, sand, and peat substrates that were used in the PSTA mesocosms and Field-Scale cells. Initial tests will be conducted at the beginning of the experiment, and selected samples will be collected and analyzed at the end of the experiment. Sorption/desorption experiments are conducted by exposing each substrate type to a range of P concentrations from 0 to 1.0 mg TP/L. These samples are purged with N_2 gas to create anaerobic conditions and placed on a mechanical shaker for 24 hours. Following equilibration, the solution phase is analyzed to determine

how much P has been sorbed in the solid phase. These soil samples are in turn exposed to water containing no spiked P, and the change in TP concentration after 24 hours is used to estimate their potential for TP desorption.

7.5.2 Dry Weight and Bulk Density

A sub-sample of each sediment sample of known volume is weighed, dried at 105ºC for 72 hours, and re-weighed to determine percentage dry weight, water content, and bulk density.

7.5.3 Accretion Rate

Sediment accretion rate will be estimated in the mesocosms by placement of horizon markers (feldspar) at the beginning of each mesocosm and Test Cell experiment. Depth to the horizon marker will be measured at the end of the study period. Accretion will also be measured using sediment traps placed in the Porta-PSTAs or along the walkways in the Test Cells and at the Field-Scale site.

7.5.4 Sediment Chemistry

Sediments are routinely sampled and analyzed for various P fractions and for N and TOC. P is routinely fractionated using the scheme illustrated in Exhibit 7-1c, which divides this element into total inorganic P (TIP) and TP. Total organic P (TOP) is determined by difference. A more detailed fractionation scheme will be employed on a subset of the sediment core samples. This fractionation method is illustrated in Exhibit 7-2 and identifies how much of the TP is in unavailable organic forms. Sediments will also be routinely analyzed for TKN and TOC. Sediment sample fractions will be composited between Porta-PSTA treatments and internal stations of each ENR South Test Cell for the analysis of non-reactive P.

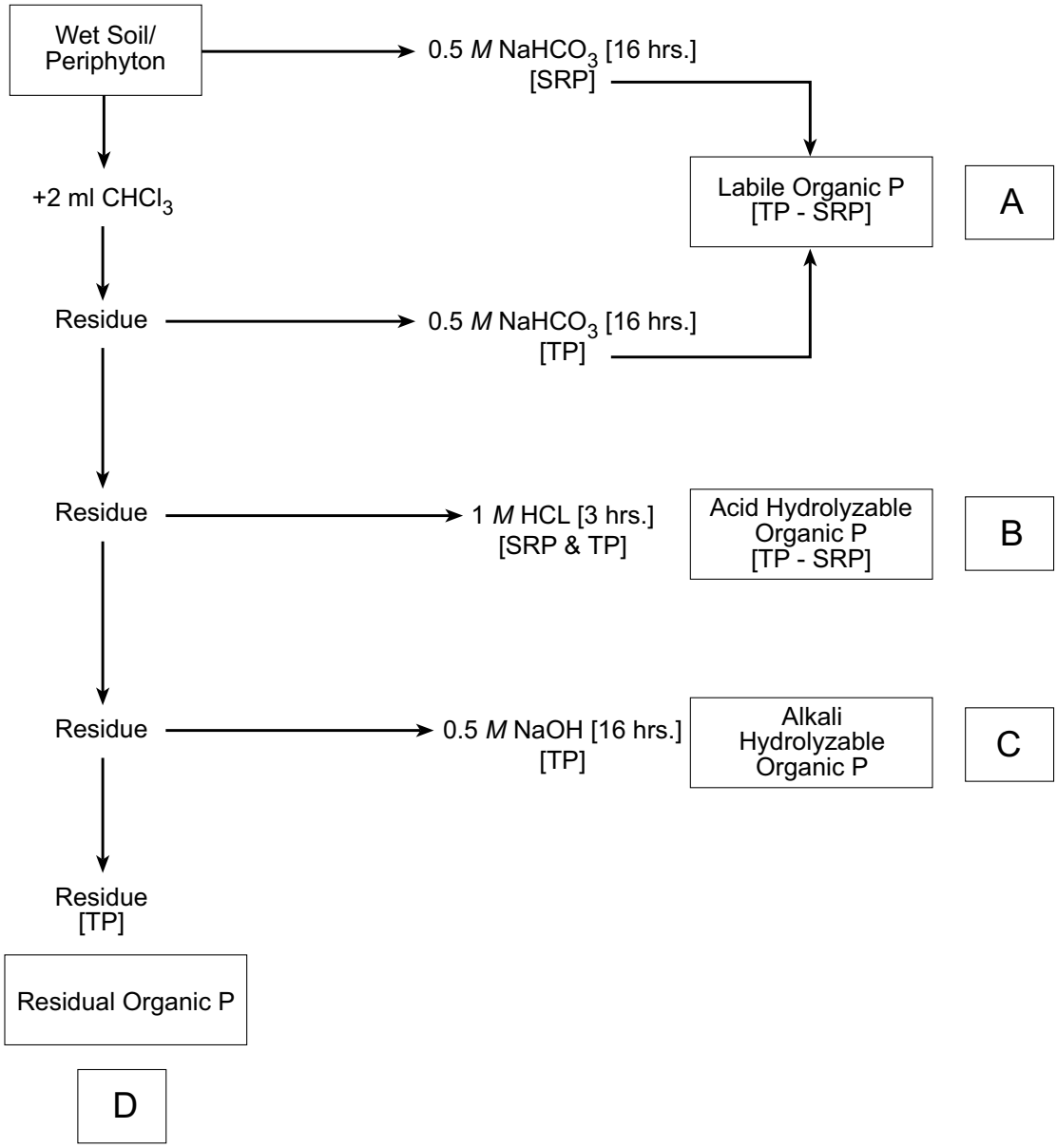
7.6 Biological Measurements

7.6.1 Population Sampling

7.6.1.1 Periphyton

Periphyton is sampled from discrete locations in the mesocosms and as a component of the whole water-column biotic community. A taxonomic list and reference collection will be maintained for dominant species of periphytic algae in each type of mesocosm during the period of research. Periphyton samples from specific habitats will be collected to develop the qualitative list of algal species that are present. These species will be recorded by their occurrence and abundance in the floating mat, metaphyton, epiphyton, or epipelon.

The entire water-column periphyton population will be sampled and integrated. A floating ring (approximately 250 cm^2) is placed on the water surface at a stratified random location. All floating algae are clipped along the inside edge of the ring, removed and transferred to the sample container. A plastic coring tube is placed through this ring and vertically lowered to the sediment surface and rotated to cut any plants or filamentous algae as it is inserted approximately 5 cm into the sediments. All macrophyte plant material is collected



Bioavailability = A > B > C > D

Exhibit 7-2. Detailed Phosphorus Fractionation Scheme for Selected Periphyton and Sediment Samples.

within this column and transferred to a Ziploc bag for dry weight analysis. All benthic, metaphyton, and epiphyton within the coring tube are collected in a decontaminated bucket. The total volume is measured and recorded, then blended with deionized water for laboratory analysis. If no periphyton mat is evident, a clear PVC corer is used to collect 3 to 6 benthic algae cores within the larger plastic coring tube. This benthic algae corer has an inside diameter of approximately 3.81 cm and a sampling area of approximately 11.4 cm^2. A stop ring is attached to the outside of the tube so that it only penetrates the sediments to a depth of 1 cm. The entire water column and benthic layer in each of these 3 to 6 samples is composited for laboratory analysis.

Cell counts and biovolumes will be reported to identify periphyton populations within the mesocosms. A complete taxonomic list of the algae present in the experimental mesocosms will be generated.

7.6.1.2 Macrophytes

Macrophytes occurring in all three mesocosm types will be identified to species, and their emergent stems will be counted (Porta-PSTAs) or estimated monthly (ENR PSTA Test Cells and Field-Scale PSTAs). Macrophyte condition including phenology, senescence, and appearance will be documented during these monthly counts. Total macrophyte biomass will be measured through destructive sampling at the end of the Porta-PSTA experiments and estimated by quadrat samples in the larger mesocosms.

7.6.2 Community Biomass

The total biomass in the water column will be sampled and analyzed as described previously. Biomass samples will be weighed wet, and then dried at 104ºC for 72 hr to get a dry weight. Samples will then be washed at 500ºC in a muffle furnace for 1 hour, allowed to cool in a dissector, and reweighed to get an AFDW and an ash weight. Percent solids will be calculated as the dry weight divided by the wet weight. AFDW is calculated subtracting the ash weight from the dry weight. All biomass results will be expressed on an area basis equal to the sampling area of the acrylic cylinder. Macrophyte dry weight and AFDW biomass will be added to the periphyton results to arrive at community biomass.

7.6.3 Plant Growth Pigments

A subsample of the periphyton biomass sample will be analyzed for chlorophyls *a*, *b*, and *c*, and for the chlorophyll breakdown product phaeophytin. These pigments help to characterize the overall proportion of the periphytic algal community in classes including green (chlorophyta) versus non-green algae (such as blue-greens). Phaeophytin content is a sensitive indicator of algal population health and decomposition.

7.6.4 P Fractionation

Exhibit 7-1c illustrates the routine P fractionation scheme that will be used on periphyton samples. These methods allow determination of TIP, TP, and TOP by difference. A more detailed P fractionation scheme will be used for a limited subset of representative periphyton samples (Exhibit 7-2). This procedure separates the bioavailable organic P from the truly unavailable organic P. Periphyton sample fractions will be composited between Porta-

PSTA treatments and internal stations of each ENR South Test Cell and Field-Scale cell for the analysis of non-reactive P.

7.6.5 Nitrogen

The organic N content of the periphyton will be determined by measuring TKN.

7.7 System-Level Parameters

7.7.1 Community Metabolism

Community metabolism can be expressed as gross primary productivity (GPP) or as community respiration (CR). These two parameters are generally similar in magnitude in adapted ecosystems (GPP:CR ratio is equal to 1). Both parameters as well as net primary productivity (NPP) will be measured in the experimental systems.

7.7.1.1 Upstream/Downstream Oxygen Method

A modified upstream-downstream oxygen rate-of-change method of Odium (1956) and Odium and Huskiness (1957) is used for measurement of community metabolism. Given the low flow rates in the mesocosms, a modified method similar to the dawn-dusk method is used. Diel oxygen concentration profiles are measured at the one- and two-third walkways in the Test Cells, at the center point of the Porta-PSTAs, and along the mid-point walkways in the Field-Scale PSTA cells. Water inflow and outflow at these stations are assumed to be negligible, and oxygen rate-of-change is determined for successive measurements at the one station rather than as the difference between upstream and downstream measurements.

Oxygen rate-of-change curves will be calculated at each station and corrected for estimated diffusion. Diffusion in the Porta-PSTAs will be eliminated during selected community metabolism measurements by covering the water surface with thin polyethylene film. Solar radiation (PAR) will be measured at the water surface during diel oxygen studies and converted to incident energy by multiplying photons (Einsteins) by a conversion factor of 52.27 Cal/Einstein calculated for sun and sky radiation (McCree, 1972).

7.7.1.2 Community Respiration

The value of the nighttime oxygen rate-of-change curve, corrected for diffusion (if necessary), provides an estimate of CR (oxygen consumption in g $O_2/m^3/hr$). Nighttime values will be averaged, multiplied by 24 hours, and multiplied by the average water depth to estimate the 24-hour community respiration in g $O_2/m^2/d$. This calculation is based on the generally accepted assumption that daytime respiration is the same as nighttime respiration.

7.7.1.3 Net Primary Production

The integrated area under the daytime oxygen rate-of-change curve, corrected for diffusion (if necessary), provides an estimate of NPP. The positive area under the daylight rate-of-change curve will be measured and multiplied by the average water depth to get the average daily NPP in g $O_2/m^2/d$. NPP can also be estimated from water-column sampling and changes in biomass summed with community export and sediment accretion.

7.7.1.4 Gross Primary Productivity

GPP is estimated as the sum of NPP and CR.

7.7.1.5 Production:Respiration Ratio

The production:respiration ratio is calculated as GPP/CR.

7.7.2 Community Export

Community export is measured directly by filtering the outflow from each type of mesocosm and determining TSS. TSS in g/m^3 is multiplied by water outflow in m^3/d and divided by mesocosm area in m^2 to get community export in g dry weight/m^2/d.

7.7.3 Periphyton Decomposition

The periphyton community decomposition rate will be measured in the mesocosms during the study period using samples of periphyton collected by core sampling, subsampling known volumes (with measured dry weight, AFDW, and P fractions), placing these subsamples in screened acrylic cylinders, and incubating these cylinders in the mesocosms for a 1-week or longer period before collection, drying, biomass determination, and P fractionation. Biomass-specific decomposition rates will be estimated from these determinations.

7.8 Laboratory Analytical Procedures

Exhibit 7-3 summarizes the analytical methods and target reporting limits for parameters monitored in the ENR Test Cells, the Porta-PSTAs, and the Field-Scale PSTA mesocosms during Phase 2 of the PSTA Research Project. Proposed bioassay methods for the testing of the PSTA Test Cells under Phase 2 are also summarized in Exhibit 7-3.

7.9 Statistical Methods

Statistical analyses will be used to determine the relative importance of critical construction and operational factors on PSTA performance. These analyses will include conventional ANOVA methods to define effects of main factors and factor interactions. Replicate results will be used in the Porta-PSTAs to estimate variability within treatments. Descriptive graphical methods, time series analysis, and experimental factor analysis will be performed. Analysis will primarily focus on the effects of different treatments on TP outflow concentrations and on TP removal rate constants.

New hypotheses that will be tested and investigations that will be performed during the Phase 2 project period include:

- Peat soils may be used with a higher level of management to improve p removal, such as the use of chemical amendments and herbicide applications.
- Limerock substrate may provide greater P removal than shellrock, and produce higher periphyton colonization rates.

Exhibit 7-3
Summary of Analytical Methods

Parameter	Analytical Method	Method Detection Limit	Units	Analytical Laboratory
Water Analyses				
Phosphorus (P) Series				
Total P	EPA 365.4	1.0	µg/L	IFAS
Total Dissolved F	EPA 365.1	1.0	µg/L	IFAS
Dissolved Reactive F	EPA 365.1	0.8	µg/L	IFAS
Nitrogen (N) Series				
Ammonia N	EPA 350.1	0.003	mg/L	PPB
Total kjeldahl N	EPA 351.2	0.040	mg/L	PPB
Nitrate+nitrite N	EPA 353.2	0.050	mg/L	PPB
Total organic carbor	EPA 415.1	0.030	mg/L	PPB
Total suspended solids	EPA 160.2	4.00	mg/L	PPB
Alkalinity	EPA 310.1	0.010	mg/L	PPB
Calcium	EPA 160.0	0.050	mg/L	PPB
Color	EPA 110.2	5.000	pcu	PPB
Turbidity	EPA 180.1	0.5	NTU	PPB
Sulfate	EPA 375.4	2.00	mg/L	PPB
Total dissolved solids	EPA 160.1	3.00	mg/L	PPB
Chloride	EPA 325.2	0.20	mg/L	PPB
Dissolved aluminum	EPA 202.2	0.00	µg/L	PPB
Dissolved magnesium	EPA 258.1	0.050	mg/L	PPB
Dissolved potassium	EPA 200.7	0.500	mg/L	PPB
Dissolved sodium	EPA 200.7	0.500	mg/L	PPB
Dissolved iron	EPA 200.7	0.010	mg/L	PPB
Dissolved silica	EPA 370.1	0.50	mg/L	PPB
Selanastrum Tests	EPA 609/9-78-018 or FDEP SOP #TA 3.3	-	mg dry weight per l	Hydrosphere
Cyprinella Tests	EPA 600-4-91-002	-	NOEC	Hydrosphere
Ceriodaphnia Tests	EPA 600-4-91-002	-	NOEC	Hydrosphere
Periphyton Analyses				
Phosphorus (P) Series				
Total P	Kuo (1996) and Anderson (1976	23	µg/g	IFAS
Total Inorganic F	Scinto, L. J, and K. R. Reddy. 1997	2.3	µg/g	IFAS
Non-reactive F	Ivanoff et al. 1998	2.3	µg/g	IFAS
Biomass (AFDW)	SM102001(5)	12.0	mg/L	PPB
Chlorophyll a, b,c, phaeophytin	SM10200H(1,2)	<1.0	mg/m^3	PPB
Total Kjeldahl N	EPA 351.4	1.00	µg/g	PPB
Calcium	EPA 200.7	0.10	mg/L	PPB
Sediment Analyses				
Phosphorus (P) Series				
Total P	Kuo (1996) and Anderson (1976	23	µg/g	IFAS
Total Inorganic F	Ivanoff et al. 1998	2.3	µg/g	IFAS
Non-reactive F	Ivanoff et al. 1998	2.3	µg/g	IFAS
Bulk density	ASTM D2957	--	g/cc	Law Engineering
Percent solids	ASTM D2937	--	%	Law Engineering
Total Kjeldahl N	COE P #3-201-3-204	10.00	mg/kg	PPB
Total organic carbor	CE-81-1-9060	1.00	mg/kg	ENCO

IFAS = University of Florida Institute of Food and Agricultural Science
NOEC = No observable effect concentratio

- The effects of higher flow velocities on TP removal rates and periphyton TP export will be investigated.
- The effects of variable depth ranging from complete dryout and re-wetting to 30 cm on PSTA performance at the Test Cells research scale will be investigated.

7.9.1 Time Series Analysis

Each treatment will be examined separately to describe trends in time, to define operational periods, describe seasonal time components, or test for autocorrelation (i.e., dependence of observations over time). Parametric and nonparametric time series techniques may be employed for this exercise. Initial startup effects, or changes in growth phase, could create trends in time in the Porta-PSTA, Test Cell, and Field-Scale effluent P concentration or periphyton biomass measurements. Changes in temperature, solar radiation, or rainfall could also create seasonal patterns in P and biomass; these can be assessed by analyzing subsets of the operational periods or through more sophisticated time-series analyses.

Operational periods will be defined depending on determination of periods of consistent, effective performance of the cells. Time series methods will be used to determine operational periods that represent an optimum period performance. The resulting operational period will be used to separate a subset of the observations for independent analysis. All analyses will be performed on the optimum subset and the full data set for comparison.

7.9.2 Graphical Descriptions

Main and interaction factor comparisons will be displayed graphically, displaying an error band to exhibit the extent of overlap, based upon experimental error. Box and whisker plots will be used to describe the distribution of TP over different treatments. These plots show the range, median, quartiles, outliers, and confidence interval around the median. Time series plots graphed separately for each treatment and overlaying different treatments on the same plot will be used for comparisons. Additional graphical techniques may include bivariate correlation plots between TP and variable treatment effects, such as depth in stacked plots called trellis plots that show differences in correlation with the influence of a third categorical variable, such as substrate.

7.9.3 Experimental Design

The experimental design used in this project is a nested block design with repeated measures. The nested block design refers to a set of experiments where each block of experiments has one factor in common. In this case, the common factor is substrate type, and then several combinations of treatments within each block, including water depth and flow velocity, are varied. It is a repeated measures design because multiple observations are taken for each experiment. The effect of time is not considered an experimental treatment, but an assessment of the long-term ability of the PSTA system to remove P. The effects of trend and seasonality are confounding effects that must be accounted for by separating subsets of the data that have consistent results of the main treatment factors.

Three sizes of PSTA mesocosms will be used in the Phase 2 period. These include the mesocosm Porta-PSTA cells, 0.5-acre Test Cells, and 5-acre Field-Scale cells in the following arrangements:

- Porta-PSTAs: 24 total cells in 12 separate treatments; 5 treatments will be continued as unaltered until early October 2000; 7 treatments will be converted to new treatments; all experiments for Phase 2 will be completed by early October 2000. Water depths, velocity, substrate type effects will be compared.
- Test Cells: 3 total cells in three separate treatments. Different Test Cells will be compared between years and treatments, as appropriate.
- Field Scale: 4 total cells in four separate treatments. Water depths, velocity, and substrate type effects will be compared.

During design of the sampling protocol for the test units, it was decided that replicate variability was a important factor to include in the design. However, given budgetary limits, a full factorial experimental design was not possible. Distinct experimental units are retained such that each of the factors may be compared with one or more pairs of test unit results, without confounding factors. The advantage of this design is the ability to discriminate statistically significant differences on a small scale while retaining the ability to test each of the primary factors. Five of the Porta-PSTA treatments had three replicates each. Neither the Test Cells nor the Field-Scale cells have replicates at the same scale. However, it will be possible to use the PSTA Test Cells and Field-Scale cells as replicates along with the Porta-PSTA cells when they have similar treatments, and thus use them in statistical tests of hypotheses. Parametric analysis of variance (ANOVA) and nonparametric Kruskal-Wallis (K-W) rank sum techniques will be used for hypothesis tests.

SECTION 8

PSTA Research Models

8.1 Model Development Goals

A full-scale PSTA is expected to undergo a highly variable hydraulic loading regime, with significant variation in water depth and velocity. The expected range of loads exceeds those that can be tested in Phases 1 and 2 of this project. A calibrated, validated PSTA performance forecast model will allow the District to close this gap in experimental conditions. With such a model, results from the field experiments currently underway could be applied to a potential full-scale operational conditioning.

Models span a broad range of data requirements and complexity. Because P removal rates can be summarized as a simple logarithmic decay (i.e., first-order process) by using inflow/outflow concentrations and hydraulic loading data, and because wetland performance is tied more closely to surface area than to water volume (Kadlec and Knight, 1996), an area-based model is typically more appropriate than a volumetric first-order model. Plug-flow hydraulics are typically assumed. For Everglades STA design, currently preferred models stem from this understanding. Several first-order design models currently in use were developed in sequence following the increasing availability of process information. Over time, these models became more complex and acquired names that facilitate their use and description:

- "k_1" – first-order, area-based removal; a "one-parameter" model
- "k-C*" – first-order, area-based removal with background "irreducible" concentration; a "two-parameter" model (Kadlec and Knight, 1996)
- Everglades Phosphorus Gradient Model – first-order model with soil storage of P (Kadlec and Walker, 1997)
- Dynamic Model for Stormwater Treatment Areas (DMSTA) – a first-order model that utilizes separate rate coefficients for settling, resuspension, and long-term storage in soils; a "four-parameter model" (Walker and Kadlec, 2000).
- "Level 2" PSTA Model – a first-order model with multiple compartments proposed as the first approach to developing a PSTA forecast model (Kadlec, 1998). This model was refined and calibrated during Phase 1 of the PSTA project, and summarized in the Phase 1 report (CH2M HILL, 2000).

At the conclusion of Phase 1, it became clear to the project team that the simplest model that effectively describes PSTA performance would provide the greatest utility. For Phase 2, the forecast model being developed is seen as an intermediate level of complexity between a dynamic ecosystem model and the first-order models listed above. The model, which builds on the earlier work by Kadlec (1996a and 1996b) and the "Biomachine" model described by Kadlec and Walker (1996), is simpler and can be simulated at this early stage of research with available data.

8.2 PSTA Applications for the k_1, k-C*, and DMSTA Models

The k_1 and k-C* models were calibrated using the results of the Phase 1 PSTA mesocosm studies. The k_1 model yielded first-order removal rates ranging up to 27 m/yr, depending upon the experimental treatment and operational period. Future activities in applying this model toward the PSTA project include continued analysis of results collected during Phase 2 from the Porta-PSTA mesocosms and Test Cells, as well as application to the data collected from the Phase 2 field-scale cells.

A second parameter representing the lowest achievable or irreducible concentration (C*) likely to occur in a treatment wetland was included in the first-order, area-based plug flow model, and termed the k-C* model. First-order k-C* models will be developed for all Porta-PSTA, Test Cell, and Field-Scale mesocosms using data collected during Phase 2. Estimates of C* and temperature correction factors will be developed, and then used to calculate first-order rate constants. First-order k-C* models will also be fitted to the data from the Phase 2 field-scale mesocosms.

From these preliminary modeling efforts, and from on-going PSTA data analyses, sediment-water interactions can be seen to strongly influence background C* values. Models that describe and predict the internal and external loading of TP are expected to provide the greatest utility in long-term planning and design. This need, as well as the need to assess system performance under highly variable hydraulic inflows, led to the development of DMSTA (Walker and Kadlec, 2000). This model tracks P in the water column, a combined storage of sediment and biota (S), and irreversible sediment burial (g), and allows estimation of first-order removal rates (k_a and k_V), resuspension (k_s), and system influx and efflux. This model offers potential application to the PSTA project. Preliminary data sets were provided to the model developers to use in calibration. Development of a "DM-PSTA" model by others is expected to continue during Phase 2, and results of the PSTA project will be forwarded to model developers as they become available.

8.3 PSTA Phase 2 Forecast Model

With the conclusion of the Phase 1 report, model development activities were shifted away from further refinement of the Phase 1 model and instead, a structurally simpler model that could be operated on a spreadsheet was designed by the project team. The Phase 2 model under development includes the following major improvements over the Phase 1 model:

- Inclusion of external forcing functions to provide the best understanding of processes that control the natural periphyton/limestone-based treatment system, including sunlight (seasonally variable), rainfall (both direct and through stormwater inputs), and wind and atmospheric inputs/outputs (evapotranspiration, diffusion of oxygen and carbon dioxide, physical mixing, resuspension, plant and animal migration, and atmospheric pollutant loads).
- Simplification of the model to require only TP data.
- Addition of a more dynamic water balance with stage-storage relationships.
- Consideration of human management influences (e.g., construction of landform, water pumping and depth control, sediment removal, maintenance, and related actions).

Exhibit 8-1 presents a diagram of the interim Phase 2 model along with the major state variable equations. The model consists of four main compartments: the water column (W), TP in the water column (P_W), biomass (B), and TP in the biomass (P_B). Each of these components is described in detail in the following paragraphs. The model also includes a labile phosphorus pool that allows for the fitting of initial TP releases to the water column. Exhibit 8-2 presents a list of the variables and the equations/data that will be used to determine each one.

Water Column (W)

The water column component is represented by a general water balance equation. The water "state" at any time is the difference between the sum of the flow inputs (i.e., pumped inflow and precipitation) and outputs (i.e., flow over the weir, evapotranspiration, and groundwater exchange).

The pumped inflow and outflow over the weir will be measured in the field. Precipitation data will be gathered using an on-site rain gauge. Evapotranspiration (ET) data available from the Everglades Nutrient Removal Project (ENR) will be used. These data will be compared against site-specific studies of diurnal changes in water level in the field-scale cells. For the field-scale PSTAs, groundwater flow will be estimated based upon differential heads between the upgradient monitor wells, cell stage, and downstream monitor wells.

Water Column TP (P_W)

TP in the water column is described as the concentration resulting from the net effects of the inflow and outflow concentrations, bulk atmospheric deposition, uptake by the biomass, losses to groundwater, and a return from sediments and biomass.

Inflow and outflow TP concentrations will be measured directly as part of the routine monitoring events. Previous District measurements of bulk atmospheric deposition will be used. Uptake by biomass will be derived from dry weight measurements of TP from algae and macrophyte samples. The return from sediments and biomass will be determined during the calibration process. These results, in turn, will be checked against the results obtained during the Phase 2 dry-down experiments in the Porta-PSTA and Test Cell experiments.

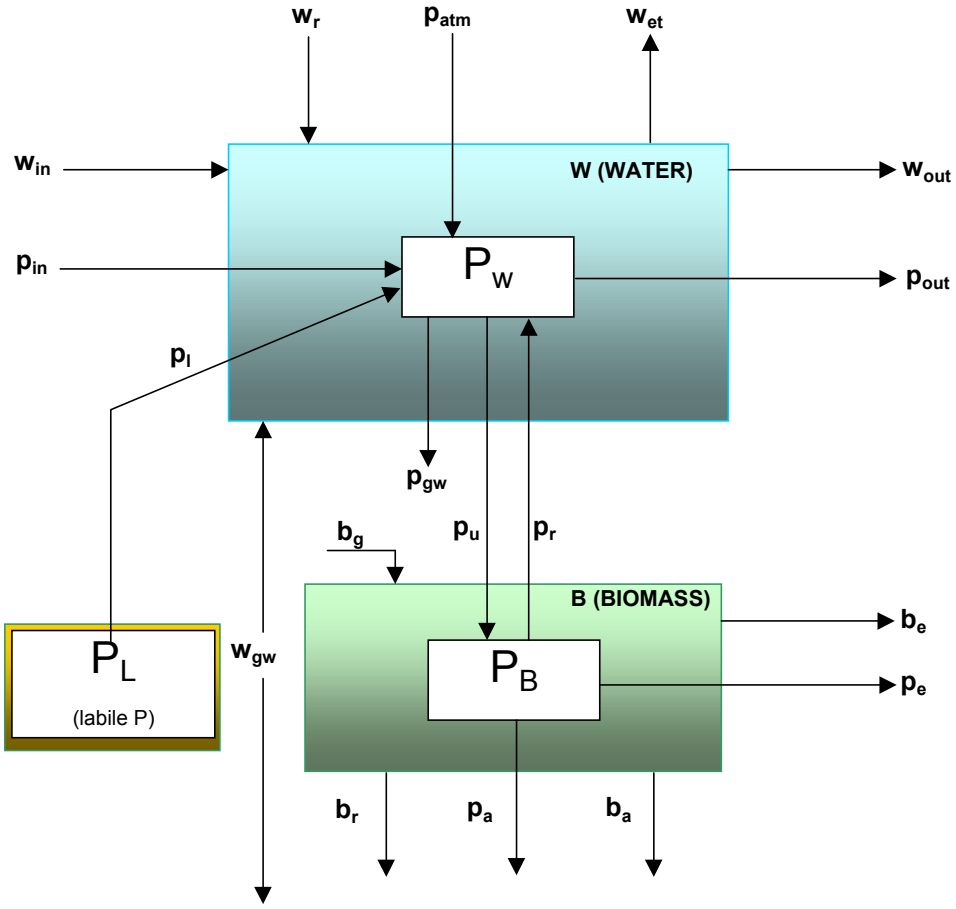
Biomass (B)

The biomass component consists of the benthic algal mat, epiphytic algae, tychoplankton, macrophytes, and detritus. The biomass state variable depends upon algal growth and death rates, algal export from the system using total suspended solids as a proxy measure, and accretion of algal solids in the detrital layer. Algal growth is calculated as a function of incident solar radiation, water column total phosphorus concentration, and antecedent biomass density. Michaelis-Menten-type models will be used to describe the relationships between these parameters and overall biomass growth.

Biomass TP (P_B)

Total phosphorus in algal biomass is modeled as a function of the rates of uptake, internal recycling, accretion, and export. Values for all rate coefficients will be initially estimated

EXHIBIT 8-1
PSTA Phase 2 - Phosphorus Forecast Model



$$\dot{W} = w_{in} - w_{out} + w_r - w_{et} - w_{gw}$$
$$\dot{P_W} = p_{in} - p_{out} + p_{atm} - p_u + p_r - p_{gw} + p_I$$
$$\dot{B} = b_g - b_r - b_e - b_a$$
$$\dot{P_B} = p_u - p_r - p_a - p_e$$
$$\dot{P_L} = - p_I$$

$\dot{W}$ = water state variable
w_{in} = pumped water supply to system
w_{out} = measured outflow from system
w_r = rainfall
w_{et} = evapotranspiration
w_{gw} = groundwater flow

$\dot{P_W}$ = TP in water column state variable
p_{in} = aerial loading rate of TP to water column
p_{out} = TP in outflow from system
p_{atm} = bulk atmospheric deposition of TP
p_u = TP uptake by biomass
p_r = TP returned from biomass to water column
p_{gw} = TP in groundwater

$\dot{B}$ = biomass (ash-free dry weight) state variable
b_g = biomass growth rate
b_r = biomass respiration rate
b_e = biomass export rate
b_a = biomass accretion rate

$\dot{P_L}$ = Labile TP state variable
p_I = TP input from initial labile storage

$\dot{P_B}$ = TP in biomass state variable
p_a = TP accretion in sediments
p_e = TP exported with biomass

EXHIBIT 8-2
PSTA Phase 2 - Phosphorus Forecast Model Equations and Data Sources

Variable		Calculated as	1° Units	Description
W	=	$W_{initial} + \dot{W}dt$	m	water
$\dot{W}$	=	$w_{in} - w_{out} + w_r - w_{et} - w_{gw}$	m/d	water rate of change
w_{in}	=	Q_{IN}	m/d	pumped inflow
w_{out}	=	applicable weir equation	m/d	water out
w_r	=	Precip * A	m/d	rainfall
w_{et}	=	ET * A	m/d	evapotranspiration
w_{gw}	=	seepage rate	m/d	groundwater exchange
P_w	=	$(P_{w\_initial} + \dot{P_w}dt)/W$	gTP/m^3	water column TP
$\dot{P_W}$	=	$p_{in} - p_{out} + p_{atm} - p_u + p_r - p_{gw}$	$gTP/m^2/d$	water column TP rate of change
p_{in}	=	$(C_{IN} * Q_{IN})/A$	$gTP/m^2/d$	TP in pumped inflow
p_{out}	=	$(P_W * Q_{OUT})/A$	$gTP/m^2/d$	TP in surface outflow
p_{atm}	=	$(C_{ATM} * Precip)/A$	$gTP/m^2/d$	bulk atmospheric deposition
p_u	=	$k_u * P_W * B$	$gTP/m^2/d$	TP uptake by biomass
p_r	=	$b_r * P_B/B$	$gTP/m^2/d$	TP returned to water column from biomass/sediments
p_{gw}	=	$P_W * w_{gw}$	$gTP/m^2/d$	TP in groundwater exchange
B	=	$B_{initial} + \dot{B}dt$	g AFDW/m^2	Biomass (ash-free dry weight)
$\dot{B}$	=	$b_g - b_d - b_e - b_a$	g AFDW/m^2/d	Biomass rate of change
b_g	=	$k_g * (I/(k_{si} + I)) * (P_W/(k_{sp} + P_W)) * B$	g AFDW/m^2/d	biomass growth
b_r	=	$k_r * B^2$	g AFDW/m^2/d	biomass respiration rate
b_e	=	$k_e B + HB$	g AFDW/m^2/d	biomass export
b_a	=	$k_a * B$	g AFDW/m^2/d	biomass accretion
H	=	user defined	d^{-1}	harvesting coefficient
P_B	=	$P_{B\text{-}initial} + \dot{P_B}dt$	gTP/m^2	TP in biomass
$\dot{P_B}$	=	$p_u - p_r - p_a - p_e$	$gTP/m^2/d$	TP in biomass rate of change
p_u	=	$k_u * P_W * B$	$gTP/m^2/d$	TP uptake by biomass growth and luxury uptake
p_r	=	$b_r * P_B/B$	$gTP/m^2/d$	TP returned to water column from biomass/sediments
p_a	=	$b_a * P_B/B$	$gTP/m^2/d$	TP in accreted biomass
p_e	=	$b_e * P_B/B$	$gTP/m^2/d$	TP exported in biomass
P_L	=	$PL_{\text{-}initial} + \dot{P_L}dt$	gTP/m^2	Initial labile TP
$\dot{P_L}$	=	$- p_l$	$gTP/m^2/d$	Labile TP rate of change
p_l	=	$k_l P_L$	$gTP/m^2/d$	TP input from initial labile storage

EXHIBIT 8-2
PSTA Phase 2 - Phosphorus Forecast Model Equations and Data Sources

Variable		Calculated as	1° Units	Description
k_g	=		d^{-1}	biomass growth rate
k_{si}	=		$E/m^2/d$	half saturation constant for PAR
k_{sp}	=		gTP/m^3	half saturation constant for water column TP
k_r	=		$m^2/gAFDW/d$	biomass respiration rate constant
k_e	=		d^{-1}	biomass export rate constant
k_a	=		d^{-1}	accretion rate constant
k_u	=		$m^3/gAFDW/d$	luxury uptake constant
k_l	=		d^{-1}	P release from labile storage rate constant
k_{net}	=	$(p_a-p_l)/P_W*365$	m/y	TP net settling rate
Q_{in}			m^3/d	inflow
Rain			m/d	rainfall
ET			m/d	evapotranspiration
Weir Ht.			ft	weir height
C_{inTP}			mgTP/L	TP inflow concentration
C_{atmTP}			mgTP/L	TP in rainfall
PAR			$E/m^2/d$	photosynthetically active radiation

using the return from the spreadsheet macros for numerical analysis. These values will be compared against direct measures of export (e.g, phosphorus content of the total suspended solids in the discharge) and accretion (e.g, settling chamber results and pre- and post-experiment sediment cores). While not measured directly, spreadsheet macro returns for internal recycling and uptake rate coefficient estimates will be compared to available data from mesocosm batch tests and reported changes in the biomass phosphorus concentration over time.

Model Calibration and Validation

Calibration of the Phase 2 model will use available data from selected Phase 1 Porta-PSTA and Test Cells. Inflow, outflow, and changes in measured state variable concentrations will be used as model inputs, and commonly accepted spreadsheet-based approaches to minimizing the least-sum-of-squares in predicted residuals will be used to calibrate model coefficients. Validation data sets are expected to include information from selected Phase 2 Porta-PSTAs, the second year of Test Cell operations, and the Field-Scale Cells. Routine quarterly reports for the project will include preliminary progress reports on model development and testing.

8. 4 Summary

The Phase 2 Forecast Model development approach will build upon the detailed k_1, k-C*, Phase 1 Level 2 model, and appropriate approaches from the DMSTA model. A simplified concept for the Phase 2 Forecast Model was developed and rate coefficients will be developed from an analysis of existing data coupled with spreadsheet macro solutions. Calibration and validation approaches will make use of the available data sets from selected Phase 1 and Phase 2 Porta-PSTAs, Test Cells, and Field-Scale Cells.

SECTION 9

Project Reports and Reviews

Data-oriented interim reports will be assembled to transmit the study results to the District, SRP members, and other interested parties during the study period. Final annual reports will be generated at the end of each study phase. The Phase 1 Summary report was submitted in August 2000.

During Phase 2, two interim reports will be generated to allow the District and SRP members the opportunity to review updated data summaries on the PSTA research. These interim reports will be tentatively submitted in January 2001 (reporting period of April 2000 to September 2000) and May 2001 (reporting period of October 2000 to December 2000).

At the end of Phase 2, the cumulative findings of the two research phases will be compiled and synthesized into a final report. This document will contain the final technical, economic, and environmental feasibility evaluations of the PSTA technology. The document will address the technology's viability in terms of being capable of reducing TP concentrations from approximately 50 ppb to levels as low as 10 ppb on a long-term average basis. It will summarize performance forecast model projections of long-term performance capacity and the likely periods during which PSTA management actions (e.g., dry down and/or sediment removal) will be needed. Finally, the document will address economic viability of the technology, as well as the quality of the PSTA "effluent" in terms of its marsh readiness.

SECTION 10

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APPENDIX A

PSTA Quality Assurance Project Plan

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
3301 Gun Club Road, West Palm Beach, Florida 33406 • (561) 686-8800 • FL WATS 1-800-432-2045 • TDD (561) 697-2574
Mailing Address: P.O. Box 24680, West Palm Beach, FL 33416-4680 • www.sfwmd.gov

ECP 18 SUP

March 26, 2001
148010.P2.02.CH

Taufiqul Aziz, Ph.D.
Florida Department of Environmental Protection
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Subject: Quality Assurance Project Plan for the Periphyton-Based Stormwater Treatment Area (PSTA) Research and Demonstration Project for the South Florida Water Management District

Dear Dr. Aziz:

In September 1999, the South Florida Water Management District (District) submitted to the Florida Department of Environmental Protection (FDEP) a Quality Assurance Project Plan (QAPP) for the Periphyton-Based Stormwater Treatment Area (PSTA) Research and Demonstration Project. Correspondence from the FDEP, dated November 4, 1999, requested additional information and provided comments on the QAPP. In response to these comments and refinements to the program, the QAPP has been revised; three copies of the document are enclosed for FDEP's review. Major revisions to the document are outlined below.

- The QAPP reflects PSTA Phase 2 work at the PSTA Test Cells within Stormwater Treatment Area 1W and the PSTA Field-Scale Cells west of STA 2. Project work at the Porta-PSTA mesocosms was completed in October 2000.
- The University of Florida Institute of Food and Agricultural Services (IFAS) and PPB Environmental Laboratories (PPB) are both identified as available to conduct phosphorus analyses for water, sediment and periphyton matrices in the enclosed document to provide management flexibility over the course of the project. However, the management decision made during the past year was to maintain IFAS as the laboratory of record for only the phosphorus analyses for the duration of the research and demonstration study.
- The original PSTA project team included Toxikon Laboratory for the analysis of water, sediment and periphyton samples. Since the submittal of the QAPP in September 1999, these chemical analyses have been re-assigned to PPB, ENCO Laboratories (ENCO) and Law Engineering (Law). Required laboratory information is provided on Tables 3.2C (ENCO), 3.2D (Law) and 3.2F (PPB). Original signature pages for the laboratories are also included with the enclosed document.

The revised document is provided for your reference and for review by FDEP's QA Section. If you have any questions regarding this submittal, please contact me at (561) 682-6661 or Steve Gong or Ellen Patterson at (954) 426-4008.

Sincerely,

Lori Wenkert
Staff Environmental Scientist
Ecological Technologies
Everglades Construction Project

Enclosures
c: Silvia Labie/FDEP
Jana Newman/SFWMD
Delia Ivanoff/SFWMD
Steve Gong/CH2M HILL
Bob Knight/WSI

Section 1.0 TITLE AND DEP APPROVAL PAGE

Quality Assurance Project Plan
for the
Periphyton-Based Stormwater Treatment Area (PSTA)
Research and Demonstration Project

Prepared by:
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Section 3 **PROJECT DESCRIPTION**

3.1 **Site Identification and History**

Site Name: PSTA Research and Demonstration Project – Phase 2

Site Address: Everglades Nutrient Removal Project
Palm Beach County, Florida

3.1.1 Site History

The South Florida Water Management District (District) is conducting research focused on determining the effectiveness and design criteria of potential advanced treatment technologies to support reduction of phosphorus (P) loads in surface waters entering the remaining Everglades. Particular focus is being placed on the treatment of surface water from the Everglades Agricultural Area (EAA) as well as Lake Okeechobee water that is diverted through the primary canal system to the Lower East Coast of Florida.

Periphyton-based stormwater treatment areas (PSTAs) are one of the advanced treatment technologies being researched by the District for potential application downstream of the macrophyte-based stormwater treatment areas (STAs). The PSTA concept was proposed for P removal from EAA waters by Doren and Jones (1996). Evaluations to date have been focused on PSTAs as post-STA treatment units intended to help achieve compliance with the anticipated ultimate total phosphorus (TP) criterion of 10 ppb or less.

3.1.2 Summary of the Historical Data –PSTAs have been operated by the District for two years. Under Phase 1, research was conducted at 24 Porta-PSTA mesocosms and three South Test Cells located within the District's Everglades Nutrient Removal (ENR) Project for the study period of February 1999 to April 2000. These data were summarized in the *PSTA Research and Demonstration Project Phase 1 Summary Report* (CH2M HILL, August 2000) distributed to the District and other interested parties (the Executive Summary is provided as Attachment A). TP removals were promising enough to continue into a Phase 2 with continued monitoring at the ENR sites along with the construction of four field scale cells west of STA 2 and east of the Miami Canal and US 27.

3.2 **Project Scope and Purpose**

3.2.1 Purpose of the Project

Prior to initiation of the District's PSTA Research and Demonstration Project in July 1998, detailed research to evaluate PSTA feasibility had not been performed. The PSTA project is designed to generate defensible technical information to evaluate the feasibility of full-scale implementation of PSTAs. Some of the key information to be generated under the project pertains to water quality and biological measures. These measures will support development of a PSTA performance forecast model that the project team will use to evaluate long-term operations and maintenance issues that can not be evaluated in the short time frame allotted to this project (approximately 3 years). The overall objectives of the study are to determine:

- If PSTA systems could be constructed (viability)
- If such constructed wetlands could achieve the level of phosphorus reduction desired (effectiveness) and if so,
- Whether the treatment performance could be sustained for long time periods allowing cost-effective integration of PSTAs with other treatment technologies (sustainability)

A two-phased approach was adopted to address the stated objectives of the PSTA concept evaluation: An Experimental Phase (Phase 1), and a Validation/Optimization Phase (Phase 2). The two phases, and types of activities that are included in each, are described as follows:

- **Phase 1 (Experimental Phase)** included development of the work plan and experimental design, initial research in three experimental test cells (PSTA Test Cells) located at the southern end of the ENR project, and construction and startup/monitoring of research using 24 portable experimental mesocosms (Porta-PSTAs). The Phase 1 experimental studies have yielded critical information needed to plan for field-scale mesocosm (Field PSTAs) design and construction in Phase 2. Development of a forecast model and associated predictive tools has occurred, along with preliminary model calibration with the Phase 1 experimental data.
- **Phase 2 (Validation/Optimization Phase) will include** continued research in the ENR PSTA Test Cells and in the Porta-PSTAs, and new studies at the field-scale pilot PSTAs under construction immediately west of STA 2. During Phase 2, the expanded database will be used to validate the performance forecast model, and develop design criteria for a full-scale PSTA system. The forecast model will be applied to provide projections of the long-term cost of implementing PSTAs to meet ultimate P reduction goals under the EFA.

In the aggregate, the PSTA Research and Demonstration Project is designed to develop defensible conclusions related to specific hypotheses that are relevant to key research questions and design issues described in the *Periphyton-Based Stormwater Treatment Area (PSTA) Research and Demonstration Plan* (CH2M HILL, 2001).

3.2.2 Intended end use of the data:

__X__ Permit Compliance
____ Feasibility Study
____ Consent Order Compliance
____ Remedial Action
____ Contamination Assessment
____ Water Quality Data Base (Specify which Data Base:_____)
____ Facility Operating Report
__X__ Other: PSTA Research and Demonstration Project

3.2.3 Projected Schedule and Scope of Work (Field Data Collection)

Projected Beginning Date: April 2000
Projected Ending Date: June 2001

Major Project Tasks (Field Data Collection)

Specific Project Activity	Scheduled Date
1. ENR PSTA Test Cell Monitoring	April 2000 – March 2001
2. Porta-PSTA Monitoring (completed)	April 2000 – October 2000
3. Field-Scale Mesocosm Monitoring	March 2001 – June 2001

Table 3.1
Summary of Historical Data
PSTA Research and Demonstration Project

Parameter	Concentration range (units)

*Phase 1 research was conducted from February 1999 to April 2000 at 24 Porta-PSTAs and three South Test Cells within the ENR. These data are summarized in the *PSTA Research and Demonstration Project Phase 1 Summary Report* (the Executive Summary is provided as Attachment A) (CH2M HILL, August 2000).

3.3 **Project Organization**

3.3.1 Project Organization – Sample collection activities will be conducted as follows:

- CH2M HILL using Comprehensive QA Plan No. 910036G
- Brown and Caldwell using Comprehensive QA Plan No. 900362

The Laboratory analytical work will be conducted as follows:

- PPB Environmental Laboratories using Comprehensive QA Plan No. 870017G
- ENCO Laboratories using Comprehensive QA Plan No. 910190
- Law Engineering using Comprehensive QA Plan No. 950024
- University of Florida Institute of Food and Agricultural Sciences (IFAS) using Comprehensive QA Plan No. 910051.
- Hydrosphere using Comprehensive QA Plan No. 960041-7

Refer to Figure 3.1 for the specific organization of this project.

3.3.2 Personnel Modifications or Additions – The following personnel are not included in the CompQAPs of the referenced organizations (include a brief description of project responsibilities):

A. Field Personnel
   1.
   2.
B. Laboratory Personnel
   1.
   2.

3.4 Project Objectives

3.4.1 Data Quality Objectives

_X_ The data quality objectives for this project are the routine QA targets listed in the laboratory CompQAP.

___ The minimum detection limits to be achieved for this study differ from the routine detection limits specified in the laboratory CompQAP and are included as part of Table 3.2.

___ The precision and accuracy requirements differ from the routine targets specified in the laboratory CompQAP and are included as part of Table 3.2.

3.4.2 Proposed samples for the project

a. See Figure 3.2 for the project locations. The Test Cells are located at the South Test Cell site within the District's Everglades Nutrient Removal Project (ENR), and the Field-Scale Cells are located west of STA 2. Schematics of the individual site layouts and sampling stations are provided under Figures 3.3 (Test Cells) and 3.4 (Field Scales Cells).

The Porta-PSTA experiments were conducted in mesocosms located at the South Supplemental Technology Research site within the ENR and were completed in October 2000. Thus, samples related to these experiments are not included in this revised QAPP.

b. See Table 3.2 of this Section for a summary of the sampling and analysis activities

3.4.3 Summary of Matrix Types, Analytical Methods and QA Targets

Field and laboratory analytical measurements are presented in Table 3.2.

Phosphorus forms in periphyton and sediment samples will be fractionated using an analytical scheme developed in the Wetland Biogeochemistry Laboratory at the University of Florida by Dr. Ramesh Reddy. Phosphorus will be routinely fractionated using the scheme illustrated in Figure 3.5, which divides this element into total inorganic P and total P. Total organic P is determined by difference. Periodically the total organic P will be further fractionated for the sediment samples to distinguish between the various reactive forms. This fractionation method is illustrated in Figure 3.6 and will be used to identify the amount of total P in unavailable organic forms.

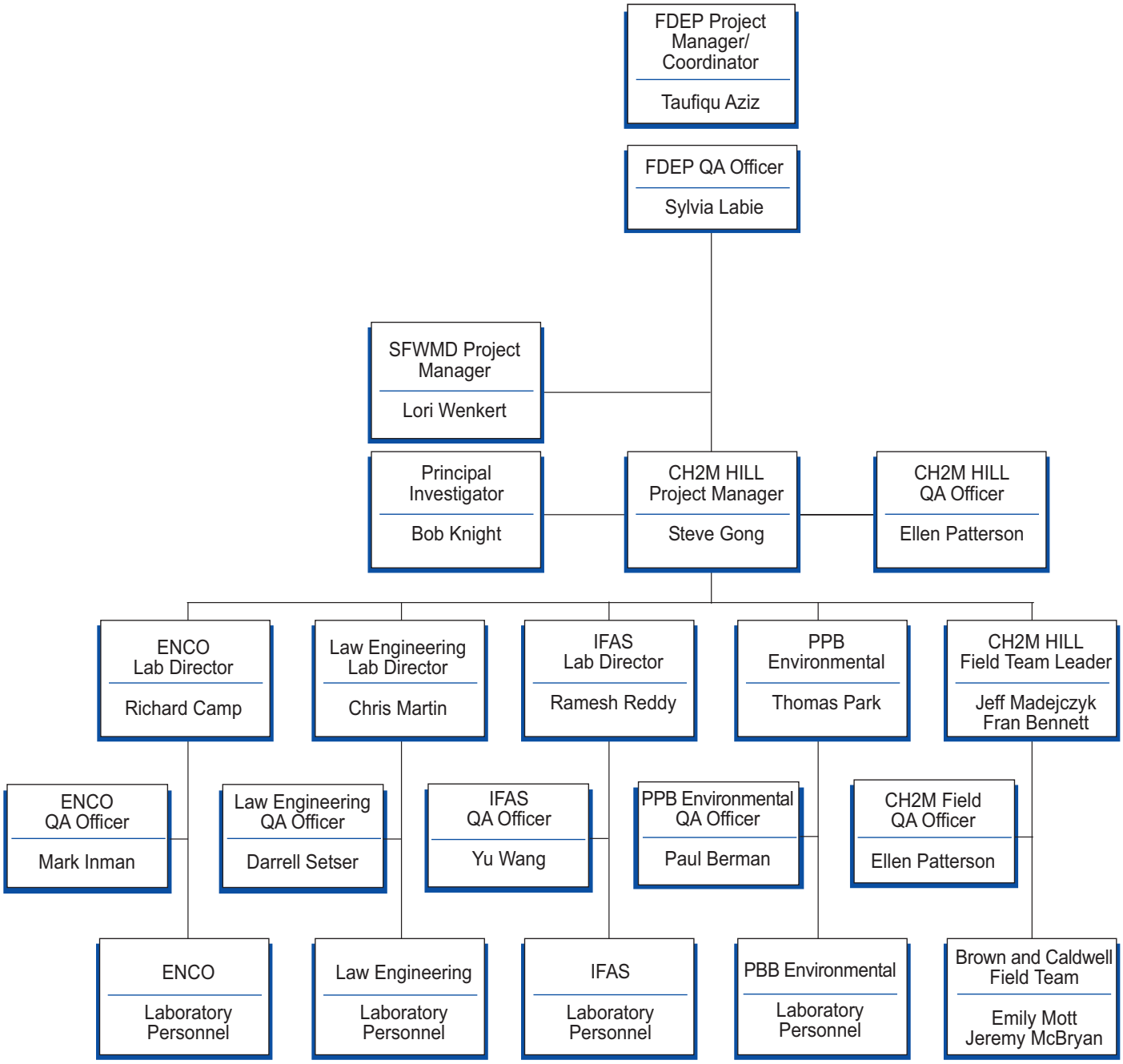


Figure 3.1
Organizational Chart for the PSTA Research and Demonstration Project, Phase 2

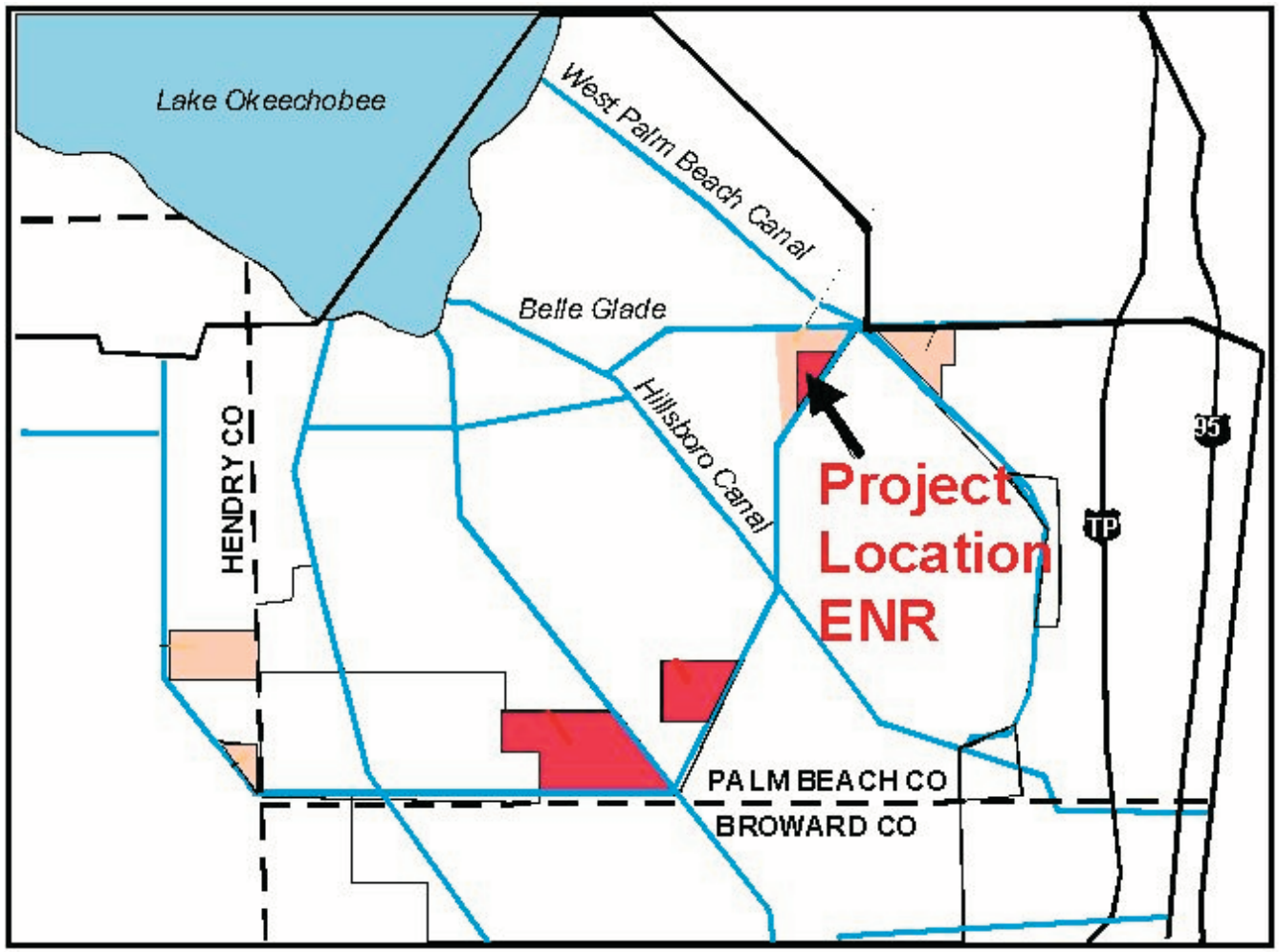


Figure 3.2
Project Location Map

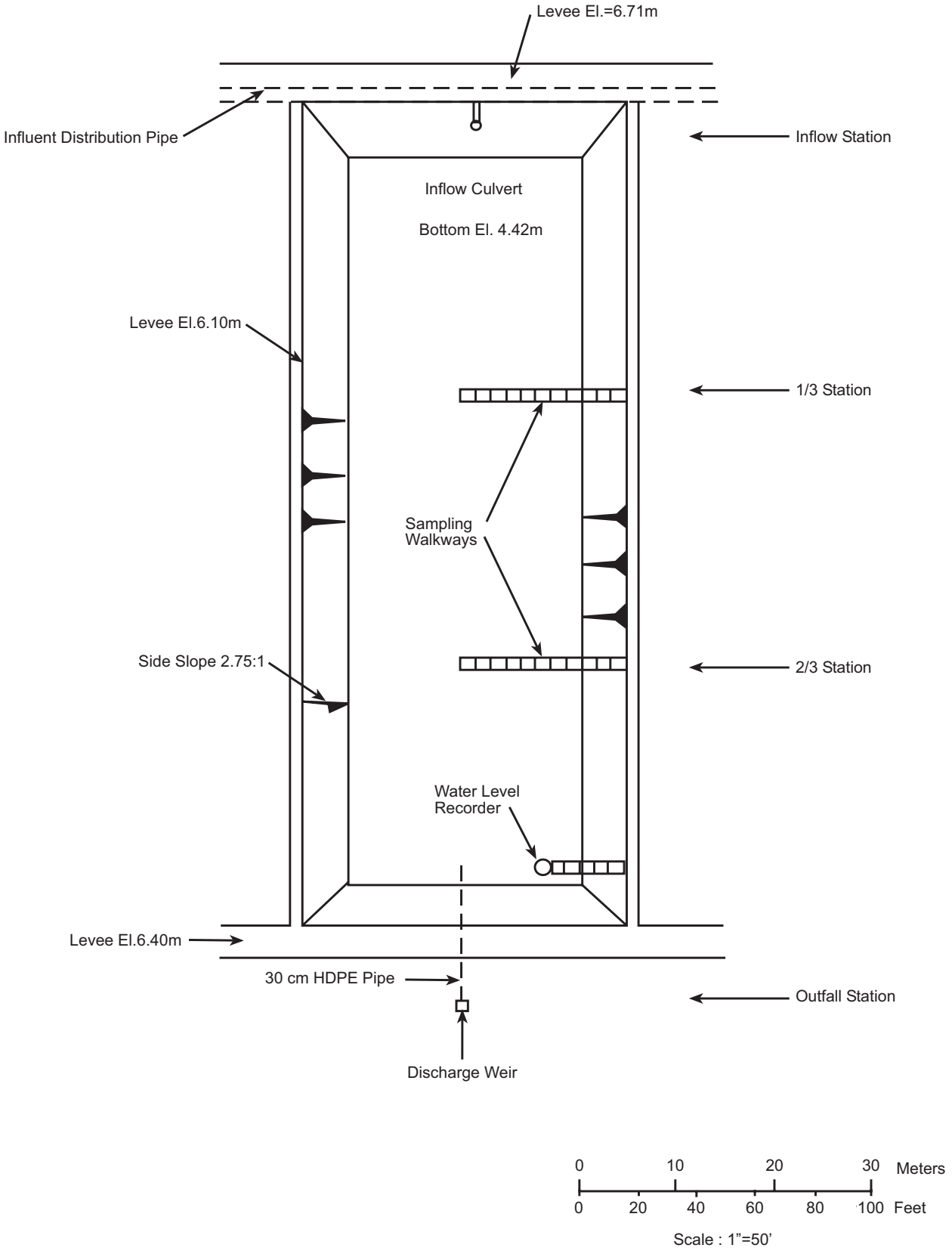


Figure 3.3. Plan View of Typical ENR PSTA Test Cell Showing Sampling Locations.

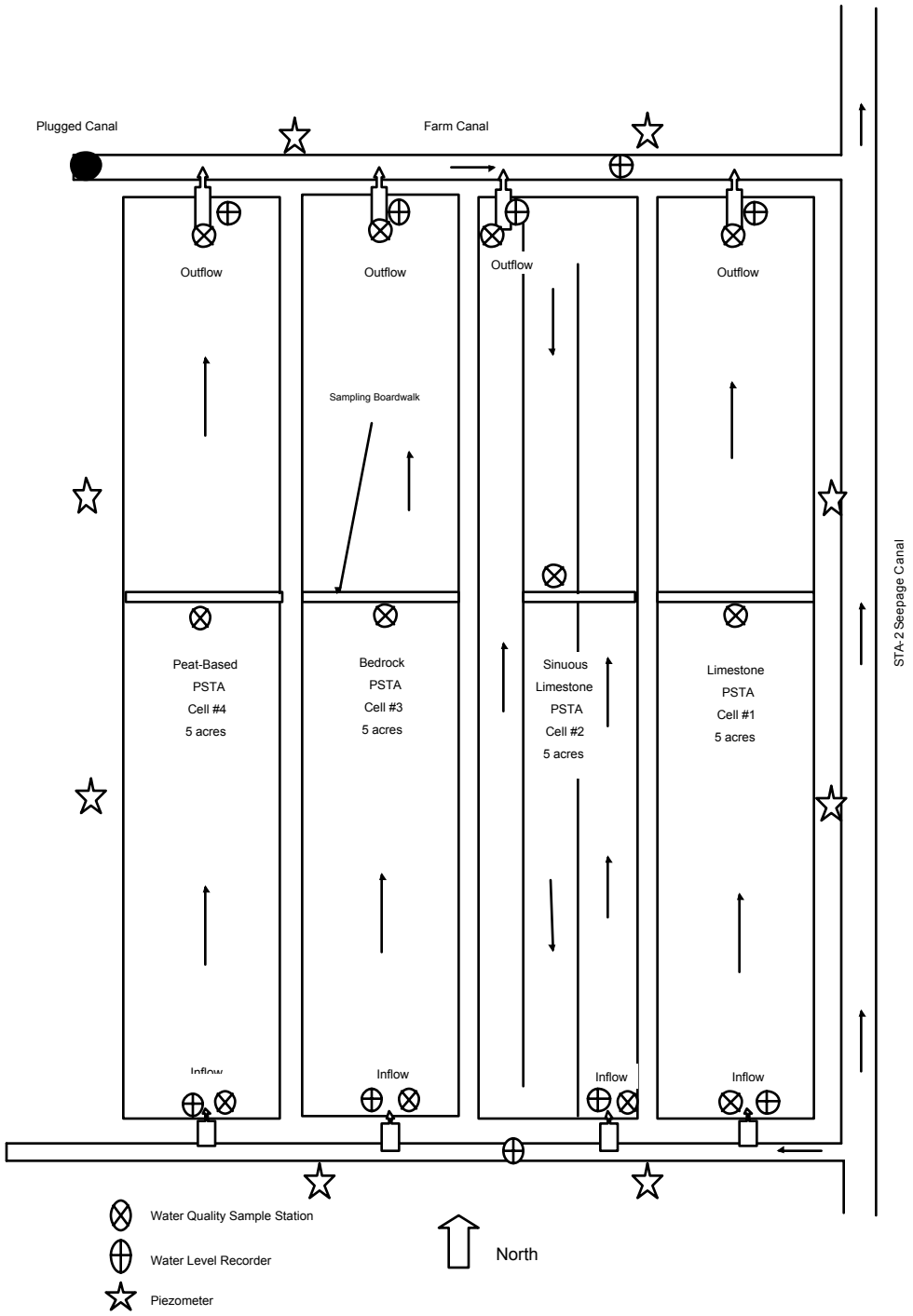
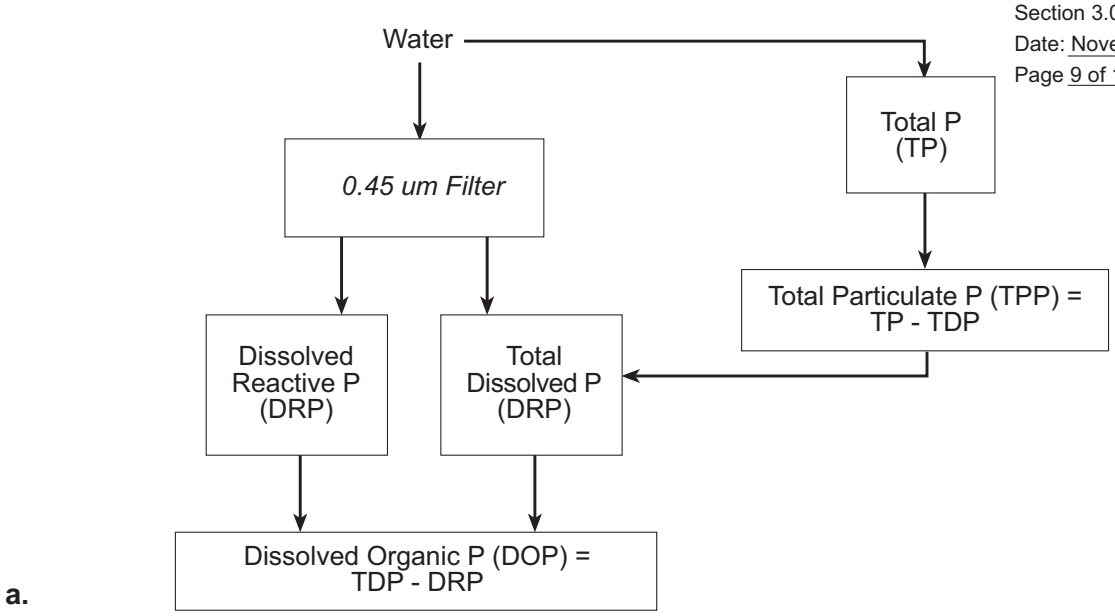
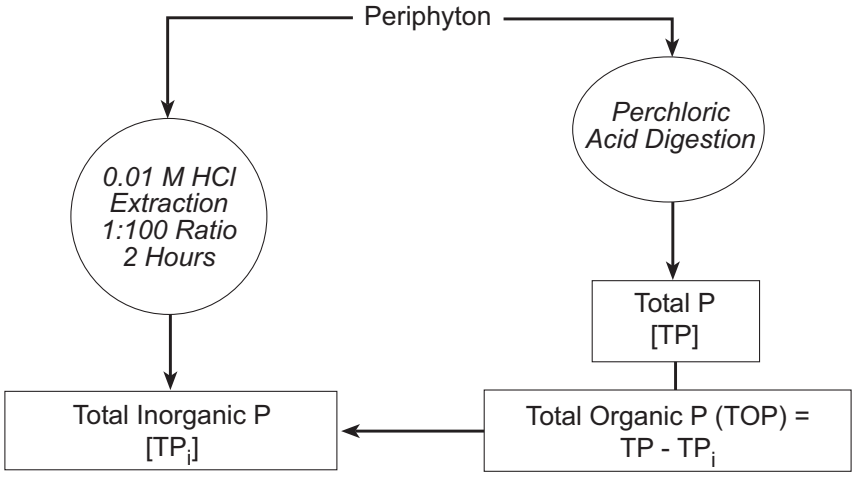


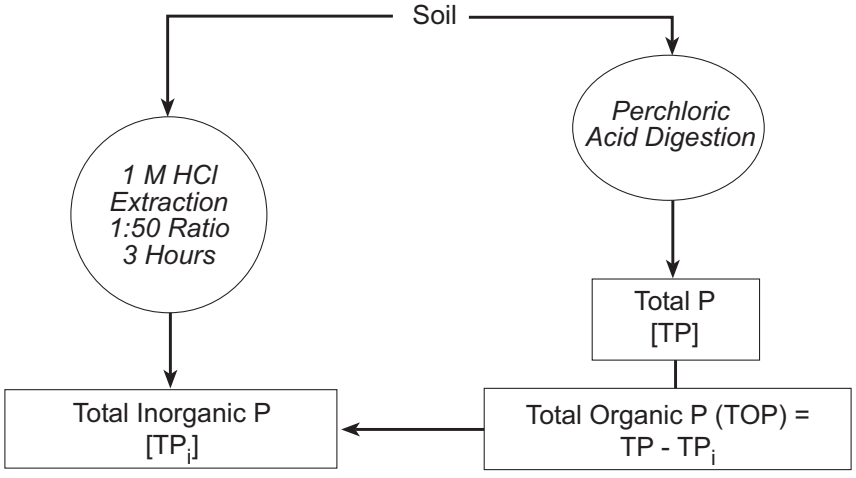
Exhibit 3.4. Schematic of Field Scale Cells Showing Sampling Locations



a.



b.



c.

Figure 3.5. Routine Phosphorus Fractionation Methods for a. Water Samples, b. Perphyton Samples, and c. Sediment Samples.

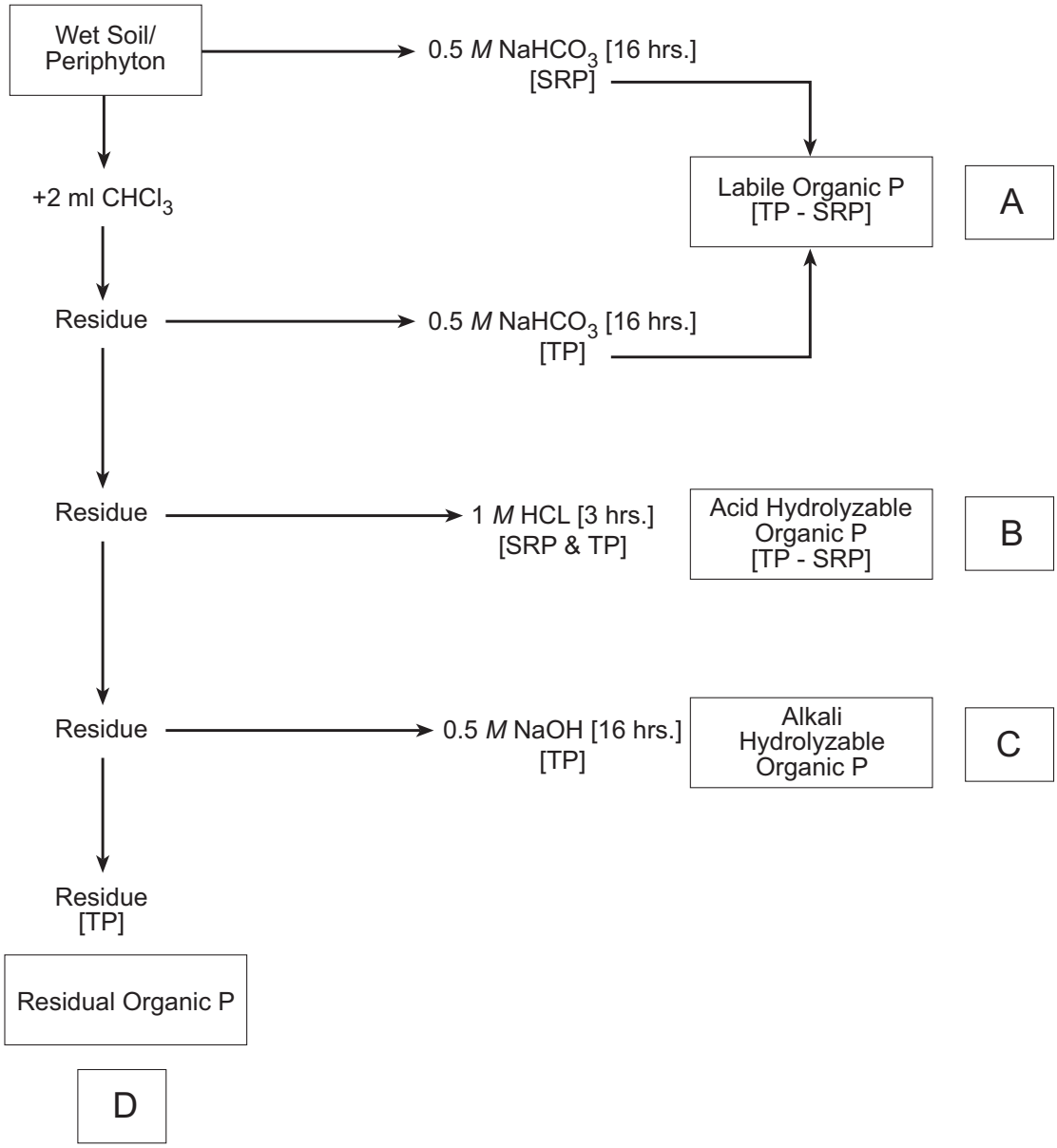


Figure 3.6. Detailed Phosphorus Fractionation Scheme for Selected Periphyton and Sediment Samples.

Table 3.2 A

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

FIELD MEASUREMENTS WILL BE PERFORMED BY: CH2M HILL whose CompQAP # is 910036G with annual amendments approved on November 30, 2000.

Parameter	**Method #**
Temperature	EPA 170.1
Dissolved oxygen	EPA 360.1
pH	EPA 150.1
Conductivity	EPA 120.1
Photosynthetically Active Radiation (PAR)	Manufacturer's specifications
Solar irradiance	Manufacturer's specifications

FIELD SAMPLE COLLECTION ACTIVITIES WILL BE PERFORMED BY THE ABOVE NAMED ORGANIZATION.

Table 3.2 B

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

FIELD MEASUREMENTS WILL BE PERFORMED BY: Brown and Caldwell whose CompQAP # is 900362 with an annual amendment approved on May 27, 2000.

Parameter	Method #
Temperature	EPA 170.1
pH	EPA 150.1
Conductivity	EPA 120.1
Photosynthetically Active Radiation (PAR)	Manufacturer's specifications
Solar irradiance	Manufacturer's specifications

FIELD SAMPLE COLLECTION ACTIVITIES WILL BE PERFORMED BY THE ABOVE NAMED ORGANIZATION.

Table 3.2C

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

LABORATORY ANALYSES WILL BE PERFORMED BY: ENCO Laboratories whose CompQAP # is 910190 with annual amendments approved on November 3, 2000.

				Quality Control Summary					QA Targets*		
Frequency	**Sample Matrix**	**Sample Source**	**# Samples**	**TB[1]**	**EB[2]**	**FD[3]**	**Analytical Method #**	**Component**	**P**	**A**	**MDL**
varies[4]	Soil	TC, FS	115	-	6	12	CE-81-1-9060	TOC	0 -18	49 -130	1 mg/kg
varies[4]	Water	TC, FS	122	-	7	13	EPA 415.1	TOC			

TB - Trip Blank
EB - Equipment Blank
FD - Field Duplicate

TC - PSTA Test Cell
FS - PSTA Field Scale Cell

P - Precision
A - Accuracy
MDL - Method Detection Limit

*These values need to be completed if the Data Quality Objectives stated in the project description are different from the routine QA objectives cited in the CompQAP(s) or are not included in the CompQAP(s).

[1]No volatile organic analyses are proposed therefore, no trip blanks are required.

[2]Equipment blanks will be collected at a rate of at least one per 20 samples. Where samples are collected directly into the sample bottles, an equipment blank will be run on a sample bottle at a rate of at least one per 20 samples.

[3]Field duplicates will be collected at a rate of at least one per 10 samples.

[4]See Tables 3.2H and 3.2I for frequency

Table 3.2D

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

LABORATORY ANALYSES WILL BE PERFORMED BY: Law Engineering whose CompQAP # is 950024 with annual amendments approved on March 24, 2000.

				Quality Control Summary					QA Targets*		
Frequency	**Sample Matrix**	**Sample Source**	**# Samples**	**TB[1]**	**EB[2]**	**FD[3]**	**Analytical Method #**	**Component**	**P**	**A**	**MDL**
varies[4]	Soil	TC, FS	115	-	-	12	ASTM D2937	Bulk Density			

TB - Trip Blank	TC - PSTA Test Cell	P - Precision
EB - Equipment Blank	FS - PSTA Field Scale Cell	A - Accuracy
FD - Field Duplicate		MDL - Method Detection Limit

*These values need to be completed if the Data Quality Objectives stated in the project description are different from the routine QA objectives cited in the CompQAP(s) or are not included in the CompQAP(s).

[1]No volatile organic analyses are proposed therefore, no trip blanks are required.

[2]Equipment blanks are not applicable to bulk density testing therefore, equipment blanks will not be collected for this parameter.

[3]Field duplicates will be collected at a rate of at least one per 10 samples.

[4]See Tables 3.2H and 3.2I for frequency

Table 3.2E

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

LABORATORY ANALYSES WILL BE PERFORMED BY: IFAS whose CompQAP # is 910051 with annual amendments approved on August 2, 2000.

				Quality Control Summary					QA Targets*		
Frequency	**Sample Matrix**	**Sample Source**	**# Samples**	**TB[1]**	**EB[2]**	**FD[3]**	**Analytical Method #**	**Component[5]**	**P**	**A**	**MDL**
varies[4]	Water	TC, FS	929	-	47	93	EPA 365.4	Total P			
varies[4]	Water	TC, FS	651	-	33	66	EPA 365.1	Total Dissolved P			
varies[4]	Water	TC, FS	587	-	59	30	EPA 365.1	Dissolved Reactive P			
varies[4]	Sediment	TC, FS	115	-	6	12	Kuo (1996) and Anderson (1976)	Total P			
varies[4]	Sediment	TC, FS	115	-	6	12	Nelson (1972)	Total Inorganic P			
varies[4]	Sediment	TC, FS	115	-	See Note 6	12	Ivanoff, Reddy, and Robinson (1998)	Non-reactive P			
varies[4]	Periphyton	TC, FS	143	-	8	15	Kuo (1996) and Anderson (1976)	Total P			
varies[4]	Periphyton	TC, FS	143	-	8	15	Nelson (1972)	Total Inorganic P			
varies[4]	Periphyton	TC, FS	49	-	See Note 6	5	Ivanoff, Reddy, and Robinson (1998)	Non-reactive P			

TB - Trip Blank
EB - Equipment Blank
FD - Field Duplicate
P - Precision
A - Accuracy
MDL - Method Detection Limit
TC - PSTA Test Cell
FS - PSTA Field Scale Cell

*These values need to be completed if the Data Quality Objectives stated in the project description are different from the routine QA objectives cited in the CompQAP(s) or are not included in the CompQAP(s).

[1]No volatile organic analyses are proposed therefore, no trip blanks are required.

[2]Equipment blanks will be collected at a rate of at least one per 20 samples. Where samples are collected directly into the sample bottles, an equipment blank will be run on a sample bottle at a rate of at least one per 20 samples.

[3]Field duplicates will be collected at a rate of at least one per 10 samples.

[4]See Tables 3.2H and 3.2I for frequency

[5]IFAS and PPB are both listed within this QAPP to perform TP, TDP, DRP and TIP analytical methods for the assigned matrices to provide management flexibility as agreed to by the District.

[6] Equipment blanks are not applicable to non-reactive P testing; therefore, no equipment blanks will be collected for this parameter.

Table 3.2F

PROPOSED SAMPLES, MATRICES AND ANALYTICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

LABORATORY ANALYSES WILL BE PERFORMED BY: PPB Environmental whose CompQAP # is 870017G with annual amendments approved on October 26, 2000.

				Quality Control Summary					QA Targets*		
Frequency	**Sample Matrix**	**Sample Source**	**# Samples**	**TB[1]**	**EB[2]**	**FD[3]**	**Analytical Method #**	**Component[6]**	**P**	**A**	**MDL**
varies[4]	Water	TC, FS	929	-	47	93	EPA 365.3	Total phosphorus			
varies[4]	Water	TC, FS	651	-	33	66	EPA 365.3	Total dissolved phosphorus			
varies[4]	Water	TC, FS	587	-	59	30	EPA 365.2	Dissolved reactive phosphorus			
varies[4]	Water	TC, FS	122	-	7	13	EPA 350.1	Ammonia N			
varies[4]	Water	TC, FS	122	-	7	13	EPA 353.2	Nitrate+nitrite N			
varies[4]	Water	TC, FS	122	-	7	13	EPA 160.2	Total suspended solids			
varies[4]	Water	TC, FS	122	-	7	13	EPA 310.1	Alkalinity			
varies[4]	Water	TC, FS	122	-	7	13	EPA 415.1	Total organic carbon			
varies[4]	Water	TC, FS	122	-	7	13	EPA 200.7/60.0	Calcium			
varies[4]	Water	TC, FS	122	-	7	13	EPA 351.2	Total Kjeldahl N			
varies[4]	Water	TC	330	-	17	33	EPA 325.2	Chloride			
varies[4]	Periphyton	TC, FS	49	-	3	5	COE P# 3-201-204	Total Kjeldahl N			
varies[4]	Periphyton	TC, FS	143	-	8	15	EPA 6010	Calcium			
varies[4]	Periphyton	TC, FS	143	-	8	15	Kuo (1996) and Anderson (1976)	Total phosphorus			
varies[4]	Periphyton	TC, FS	143	-	8	15	Nelson (1972)	Total inorganic phosphorus			
varies[4]	Periphyton	TC, FS	143	-	8	15	SM 10200H (1,2)	Chlorophyll a, b, c, phaeophytin			
varies[4]	Periphyton	TC, FS	143	-	8	15	SM 10200I (5)	Biomass[5]	25%		10 mg/L
varies[4]	Sediment	TC, FS	115	-	6	12	Kuo (1996) and Anderson (1976)	Total phosphorus			
varies[4]	Sediment	TC, FS	115	-	6	12	Nelson (1972)	Total inorganic phosphorus			
varies[4]	Sediment	TC, FS	115	-	6	12	COE P# 3-201-204	Total Kjeldahl N			
6 events	Water	TC	18	-	1	2	EPA 375.4	Sulfate			
5 events	Water	TC	15	-	1	2	EPA 202.2/200.7[7]	Aluminum (dissolved)			
5 events	Water	TC	15	-	1	2	EPA 200.7	Iron (dissolved)			
5 events	Water	TC	15	-	1	2	EPA 200.7	Magnesium (dissolved)			
5 events	Water	TC	15	-	1	2	EPA 258.1	Potassium (dissolved)			
5 events	Water	TC	15	-	1	2	EPA 370.1	Reactive Silica			
5 events	Water	TC	15	-	1	2	EPA 200.7	Sodium (dissolved)			
6 events	Water	TC	18	-	1	2	EPA 160.1	Total dissolved solids			
6 events	Water	TC	18	-	1	2	EPA 110.2	Color			
6 events	Water	TC	18	-	1	2	EPA 180.1	Turbidity			

TB - Trip Blank
EB - Equipment Blank
FD - Field Duplicate

TC - PSTA Test Cell
FS - PSTA Field Scale Cell

P - Precision
A - Accuracy
MDL - Method Detection Limit

*These values need to be completed if the Data Quality Objectives stated in the project description are different from the routine QA objectives cited in the CompQAP(s) or are not included in the CompQAP(s).

[1]No volatile organic analyses are proposed therefore, no trip blanks are required.

[2]Equipment blanks will be collected at a rate of at least one per 20 samples. Where samples are collected directly into the sample bottles, an equipment blank will be run on a sample bottle at a rate of at least one per 20 samples.

[3]Field duplicates will be collected at a rate of at least one per 10 samples.

[4]See Tables 3.2H and 3.2I for frequency

[5]Biomass is determined from ash free weight determined by gravimetric analysis.

[6]IFAS and PPB are both listed within this QAPP to perform TP, TDP, DRP and TIP analytical methods for the assigned matrices to provide management flexibility as agreed to by the District.

[7]Aluminum samples below approximately 100 µg/L are analyzed by EPA 202.2 (GFAA); samples above approximately 100 µg/L are analyzed by EPA 200.7 (ICP).

Table 3.2G

PROPOSED SAMPLES, MATRICES AND ANALTYICAL METHODS FOR THE PROJECT

The standards criteria outlined in DEP Rule 62-302 are the detection limit criteria for this project. The detection limits reported for this project shall at least meet, or be lower than the stated standards.

LABORATORY ANALYSES WILL BE PERFORMED BY: Hydrosphere whose CompQAP # is 960041-7 with annual amendments approved on October 6, 1999.

				Quality Control Summary					QA Targets*		
Frequency[4]	**Sample Matrix**	**Sample Source**	**# Samples**	**TB[1]**	**EB[2]**	**FD[3]**	**Analytical Method #**	**Component**	**P**	**A**	**MDL**
TBD	Water	Test Cells	15 (max)	-	-	-	EPA 609/9-78-018 or FDEP SOP#TA 3.3	*Selanastrum* Tests			
TBD	Water	Test Cells	15 (max)	-	-	-	EPA 600-4-91-002	*Cyprinella* Tests			
TBD	Water	Test Cells	15 (max)	-	-	-	EPA 600-4-91-002	*Ceriodaphnia* Tests			

*These values need to be completed if the Data Quality Objectives stated in the project description are different from the routine QA objectives cited in the CompQAP(s) or are not included in the CompQAP(s).

[1]No volatile organic analyses are proposed therefore, no trip blanks are required.

[2]QA/QC field samples are not applicable to bioassay testing; therefore, equipment blanks will not be collected for these methods.

[3]QA/QC field samples are not applicable to bioassay testing; therefore, field duplicates will not be collected for these methods.

[4]See Table 3.2H for frequency

TBD = To be determined

Table 3.2H
PROPOSED TEST CELL SAMPLING FREQUENCY
Phase 2 PSTA Test Cell Sampling Plan (November 2000 - March 2001) - SRP Workshop

		Sample Frequency			
Parameter	**Sampling Period (months)**	**Combined Inflow**	**Inflow**	**2/3**	**Outflow**
Field Sampling					
Flow	5	C(I)	W	NS	W
Water temperature	5	C(I)	W	M	W
Dissolved oxygen	5	C(I)	W	M	W
pH	5	C(I)	W	M	W
Conductivity	5	C(I)	W	M	W
PAR	5	NS	NS	M	NS
Water Quality Analyses					
Phosphorus (P) Series					
Total P	5	W	M	Q	W
Dissolved Reactive P	5	M	M	Q	M
Total Dissolved P	5	W	M	Q	W
Nitrogen (N) Series					
Total N	5	M	Q	Q	M
Ammonia N	5	M	Q	Q	M
Total kjeldahl N	5	M	Q	Q	M
Nitrate+nitrite N	5	M	Q	Q	M
Total organic carbon	5	M	Q	Q	M
Total suspended solids	5	M	Q	Q	M
Calcium	5	M	Q	Q	M
Alkalinity	5	M	Q	Q	M
Biological Analyses					
Periphyton Cover	5	NS		M	
Macrophyte Cover	5	NS		M	
Periphyton Dominant Species	5	NS	NS	Q	NS
Biomass (AFDW)	5	NS	NS	M	NS
Calcium	5	NS	NS	M	NS
Cholorophyll a, b,c, phaeophytin	5	NS	NS	M	NS
Phosphorus (P) Series					
Total P	5	NS	NS	M	NS
Total Inorganic P	5	NS	NS	M	NS
Non-reactive P	5	NS	NS	Q	NS
Total kjeldahl N	5	NS	NS	Q	NS
Sediments					
Phosphorus (P) Series					
Total P	5	NS	NS	E	NS
Total Inorganic P	5	NS	NS	E	NS
Non-reactive P	5	NS	NS	E	NS
Phosphorus Sorption/Desorption	5	NS		E	
Total kjeldahl N	5	NS	NS	E	NS
Total organic carbon	5	NS	NS	E	NS
Bulk density	5	NS	NS	E	NS
Solids (percent)	5	NS	NS	E	NS
Accretion	5	NS	NS	Q	NS
System-Level Parameters					
Gross primary productivity	5	NS		Q	
Net primary productivity	5	NS		Q	
Community respiration	5	NS		Q	
Standard of Comparison Sampling (Shifted Over From Field Scale)[1]					
Sulfate, Total Dissolved Solids	5-weeks	NS	5X	NS	5X
Dissolved ions/metals (Al, Fe, Ca, Mg, K, Si, Na, Cl)	5-weeks	NS	5X	NS	5X
Turbidity, Color	5-weeks	NS	5X	NS	5X
Mercury (methylated)	--	NS	(D)	NS	(D)
Algal growth potential and chronic toxicity - *Selenastrum*	--	NS	1X	NS	1X
Chronic toxicity - *Cyprinella*	--	NS	1X	NS	1X
Chronic toxicity - *Ceriodaphnia*	--	NS	1X	NS	1X

[1] STSOC testing will be performed on the combined inflow (Head Cell) and the outflows from Test Cells 8 and 13.

Notes:

Assumes number of mesocosms = 3

W = weekly
M = monthly
Q = quarterly
A = annually

(D) = sampled by District
C(I) = continuous with instrument
NS = not sampled
na = not applicable
E = End of study phanse

Table 3.2I
PROPOSED FIELD-SCALE CELL SAMPLING FREQUENCY
Phase 2 Field Scale Pilot PSTA Monitoring Plan - SRP Workshop
(Monitoring to be conducted for Cells 1, 2, 3, & 4)

		Sampling Locations and Frequency					
Parameter	Sampling Period (months)	Piezometers	Inflow Canal	Inflow	1/2	Outflow	Outflow Canal
Field Meter Readings							
Flow	8	na	na	Pump	na	calc	na
Water Stage	8	W	C(I)	W	W	C(I)	C(I)
Water temperature	8	W	W	W	W	C(I)	na
Dissolved oxygen	8	na	W	W	W	C(I)	na
pH	8	W	W	W	W	C(I)	na
Conductivity	8	W	W	W	W	C(I)	na
Total Dissolved Solids (note a)	8	W	W	W	W	C(I)	na
Turbidity (note a)	8	W	W	W	W	C(I)	na
PAR	8	na	na	na	M	na	na
Water Quality Analyses							
Phosphorus (P) Series							
Total P	8	M	NS	W	M	W	NS
Dissolved Reactive P	8	NS	NS	W	M	W	NS
Total Dissolved P	8	NS	NS	W	M	W	NS
Nitrogen (N) Series	8						
Total N	8	NS	NS	M	Q	M	NS
Ammonia N	8	NS	NS	M	Q	M	NS
Total kjeldahl N	8	NS	NS	M	Q	M	NS
Nitrate+nitrite N	8	NS	NS	M	Q	M	NS
Total suspended solids	8	NS	NS	M	Q	M	NS
Total organic carbon	8	NS	NS	M	Q	M	NS
Calcium	8	NS	NS	M	Q	M	NS
Alkalinity	8	NS	NS	M	Q	M	NS
Chlorides	8	M	NS	M	Q	M	NS
Biological Analyses							
Periphyton Cover	8	NS	NS	NS	M	NS	NS
Macrophyte Cover	8	NS	NS	NS	M	NS	NS
Periphyton Dominant Species	8	NS	NS	NS	Q	NS	NS
Biomass (AFDW)	8	NS	NS	NS	M	NS	NS
Calcium	8	NS	NS	NS	M	NS	NS
Cholorophyll a, b,c, phaeophytin	8	NS	NS	NS	M	NS	NS
Phosphorus (P) Series							
Total P	8	NS	NS	NS	M	NS	NS
Total Inorganic P	8	NS	NS	NS	M	NS	NS
Non-reactive P	8	NS	NS	NS	Q	NS	NS
Total kjeldahl N	8	NS	NS	NS	Q	NS	NS
Accretion (Net Organic/Inorganic)	8	NS	NS	NS	Q	NS	NS
Sediments (Start and End)							
Phosphorus (P) Series							
Total P	8	NS	NS	NS	S/E	NS	NS
Total Inorganic P	8	NS	NS	NS	S/E	NS	NS
Non-reactive P	8	NS	NS	NS	S/E	NS	NS
Phosphorus Sorption/Desorption	8	NS	NS		S/E		NS
Total kjeldahl N	8	NS	NS	NS	S/E	NS	NS
Total organic carbon	8	NS	NS	NS	S/E	NS	NS
Bulk density	8	NS	NS	NS	S/E	NS	NS
Solids (percent)	8	NS	NS	NS	S/E	NS	NS
System-Level Parameters							
Gross primary productivity	8	NS	NS		C(I)		NS
Net primary productivity	8	NS	NS		C(I)		NS
Community respiration	8	NS	NS		C(I)		NS

Notes:

note a = presumes Hydrolab sensor available
W = weekly
M = monthly
Q = quarterly
(D) = sampled by District
C(I) = continuous with instrument
NS = not sampled
S/E - start and end of study phase
na = not applicable
Assumes number of piezometers = 12
Assumes number of mesocosms = 4

Section 4.0 **FIELD PROCEDURES AND QUALITY CONTROL**

This section specifies the protocols and procedures to be used by CH2M HILL and Brown and Caldwell when conducting sampling activities for this project.

4.1 **Sampling Equipment**

See Table 4.1 for a list of the equipment to be used for this project.

4.2 **Field Activities** – See Table 4.2

4.2.1 Sampling protocols for this project that are not specified by the CompQAP specified in Table 4.2 include the following:

a. Water Column

Periphyton and macrophytes within the water column of the PSTA mesocosms will be sampled using the method presented below. This method will be refined throughout the project as field conditions change; the QAPP will be updated to reflect changes to the sampling method as necessary.

- A floating ring (approximately 250 cm^2) will be placed on the water surface at a stratified random location. All floating algae will be clipped along the inside edge of the ring, removed and transferred to the sample container.
- A plastic coring tube (approximately 17.8 cm diameter, 250 cm^2) will be placed through this ring and vertically lowered to the sediment surface and rotated to cut any plants or filamentous algae as it is inserted about 5 cm into the sediments. All macrophyte plant material will be collected within this column and transferred to a ziploc bag for dry weight analysis. All benthic, metaphyton and epiphyton within the coring tube will be collected in a decontaminated bucket. The total volume will be measured and recorded, then blended with deionized water for laboratory analysis.
- If no periphyton mat is evident, a clear PVC corer will be used to collect 3-6 benthic algae cores within the larger plastic coring tube. This benthic algae corer will have an inside diameter of approximately 3.81 cm and a sampling area of approximately 11.4 cm^2. A stop ring will be attached to the outside of the tube so that it only penetrates the sediments to a depth of 1 cm. The entire water column and benthic layer in each of these 3-6 samples will be composited for laboratory analysis.

The composite core sample will be blended, its volume measured, and then subsampled for the following analyses:

- Biomass
- Chlorophyll/phaeophytin
- Calcium
- Total phosphorus
- Total inorganic phosphorus
- Non-reactive phosphorus
- Total kjeldahl nitrogen
- Preserved algae
- Unpreserved algae

The analytical results for the subsamples will be related to the initial 250 cm^2 sample area and will be reported in units per square meter.

TABLE 4.1
PROPOSED SAMPLING EQUIPMENT

The following equipment will be used by CH2M HILL and Brown and Caldwell for this project. With the exception of the additional equipment, discussion on use ar included in CompQAP # 910036G for CH2M HILL updated with an annual amendment approved on October 19,1999 and in CompQAP #900362 for Brown and Ca annual amendment approved on May 27, 2000.

EQUIPMENT DESCRIPTION	CONSTRUCTION MATERIALS	USE
Purging Equipment (include construction of tubing, tail pipes, etc.)		
1. N/A		
2.		
3.		
4.		
5.		
Sampling Equipment		
1. ISCO automatic samplers	N/A	Collect surface water samples
2. Peristaltic pumps	N/A	Filter orthophosphorus samples
3. Tubing	c/flex	Filter orthophosphorus samples
4. 0.45 micron filters	N/A	Filter orthophosphorus samples
5. Sample container	Plastic/glass	Collect surface water /sediment samples
Additional equipment not addressed in the CompQAP includes[1]		
1. PAR sampling equipment		
2. Plastic coring tube (periphyton/sediment)		
3. Stainless steel coring tube (sediment)		
4. Plastic buckets (periphyton)		
Field Measurement Equipment (construction does not need to be specified)		
1. Hydrolab MiniSonde Multiprobe - conductivity, pH, temperature, dissolved oxygen		
2. LI-COR Pyranometer Sensor (LI-200SA) - Solar irradiance		
3. LI-COR Quantum Sensor (LI-190SA) - PAR		
4. LI-COR Quantum Sensor (LI-193SA) - PAR		
5.		

[1]If the sampling protocols for using this equipment are not included in the cited CompQAP, the sampling protocols must be discussed in Section 4.2.1 of this Quality Assurance Project Plan.

b. Periphyton Floating Mat

The periphyton floating mat will be estimated by single observer as percent cover during each monthly sampling event.

c. Emergent Macrophyte Stem Density

Macrophyte stem density will be estimated by a single observer as percent cover in both the test cells and field scale cells during each monthly sampling event.

d. Soil Sampling

PSTA soil samples will be collected within the same large core cylinders used for biological sampling described above. Soil samples will be collected from the top 10 cm of the sediment by a hand augar at the test cells. These samples will be placed in sample containers and refrigerated until analysis.

The hand auger method is currently proposed soil sampling method for use at the field scale cells, as well. However, due to the soil characteristics at this site (caprock and limerock), the hand auger method may not be feasible at which time alternative methods will be tested. If new methods are required at the field-scale cells, the QAPP will be revised accordingly.

e. Surface Water Sampling

Surface water samples from within the test cells or field scale cells will be collected by immersing the sample bottle to mid-depth and directly filling the bottle. Inflow and outflow samples will be collected by directly filling the sample bottle from the inflow or outflow stream. Composite samples, where required, will be collected using automatic samplers.

4.2.2 Disposal protocols for handling wastes that differ from those specified by the CompQAP. Wastes will be handled according to the following protocols: None

4.3 Field Measurements

Field measurements are listed in Table 3.2 of this QAPP. Light measurements will be made as follows:

1. Solar Irradiance. A LI-COR Pyranometer Sensor (LI-200SA) will be used to measure global solar radiation (sun plus sky). Typical accuracy is +/-5 percent.

2. Photosynthetically Active Radiation (PAR). A LI-COR quantum sensor (LI-190SA) will be used to measure phytosynthetic photon flux density in the range of 400 to 700 nanometers above the water surface of the PSTAs. Typical calibration accuracy is +/- 5 percent.

3. PAR. A LI-COR underwater spherical quantum sensor (LI-193SA) will be used to measure photosynthetic flux fluence rate within the water column of the PSTA mesocosms. Measurements will be collected with depth in the water column. Typical calibration accuracy is +/- 5 percent.

Table 4.2

FIELD ACTIVITIES

CH2M HILL and Brown and Caldwell will use the following field protocols. The Comprehensive QA Plan number for CH2M HILL is 910036G. An update to this QA plan was approved on October 19, 2000. The Comprehensive QA Plan number for Brown and Caldwell is 900362. An update to this QA plan was approved on May 27, 2000.

All protocols, procedures and policies in the above-mentioned document that are pertinent to this Quality Assurance Project Plan will be followed and are summarized below.

	VOCs	Extr. Org.	Metals	Inorg. Anions	Org.	Phys. Prop.	Micro	Other (specify)
Groundwater				X				
Groundwater (in-place plumbing)								
Potable Water								
Surface Water			X	X		X		
Soil								
Sediment/Sludges			X	X		X		
Automatic Samplers				X				
Field Filtration				X				
Wastewater								
Stormwater runoff								
Periphyton			X	X		X		Chlorophyll Phaeophytin

SAMPLE CONTAINERS

Sample containers will be supplied by: CH2M HILL, Hydrosphere and PPB Environmental*

X Sample containers will be pre-preserved by the above-referenced organization and additional acid will be provided; (PPB will provide pre-preserved sample bottles)

OR

X Field organizations will preserve samples on site using protocols outlined in the CompQAP. (CH2M HILL provides sample bottles for the IFAS samples and will preserve the samples onsite.)

EQUIPMENT DECONTAMINATION

Equipment decontamination will follow protocols outlined in the CH2M HILL's CompQAP.*

EQUIPMENT WILL BE STORED AND CLEANED ON-SITE.

***If more than one organization is involved with these activities, this QAPP must specifically identify the equipment and/or sample containers to be provided by each organization.**
(NOTE: Equipment will be provided by CH2M HILL.)

WASTE DISPOSAL

X The procedure for handling wastes from equipment cleaning and from sampling are discussed in the CH2M HILL's CompQAP.

___ The disposal procedures for handling wastes for this project differ from those outlined in the above-referenced CompQAP and are outlined in Section 4.2.2.

Section 5.0A **LABORATORY PROCEDURES AND QUALITY CONTROL**

The laboratory analyses shall be conducted by IFAS (Phosphorus, see Table 3.2E).

The Comprehensive QA Plan number for this organization is 910051.

The date of the last update approval is August 2, 2000.

All protocols, procedures and policies in the above-referenced document that are pertinent to this Quality Assurance Project Plan shall be followed. The laboratory shall analyze the samples for this project by the methods specified in Table 3.2 of the QAPP.

5.1 **Quality Control Checks**

The types of laboratory control checks that will be used when analyzing samples for this project are:

Chemical:

X	Reagent Blanks	X	Matrix Spikes
X	Duplicate Samples	____	QC Check Samples
X	Duplicate Matrix Spikes	X	QC Check Standards
X	Continuing Calibration Stnds		
____	Other:_____		

Microbiology: Not applicable

____	Duplicates	____	Control Blanks (MF)
____	Carry over blanks (MF)	____	Dilution Blanks (MPN)
____	Positive & Negative Controls		
____	Other:_____		

Section 5.0B **LABORATORY PROCEDURES AND QUALITY CONTROL**

The laboratory analyses shall be conducted by PPB (Phosphorus, Nitrogen and General, see Table 3.2F)

The Comprehensive QA Plan number for this organization is 870017G.

The date of the last update approval is October 26, 2000.

All protocols, procedures and policies in the above-referenced document that are pertinent to this Quality Assurance Project Plan shall be followed. The laboratory shall analyze the samples for this project by the methods specified in Table 3.2 of the QAPP.

5.1 **Quality Control Checks**

The types of laboratory control checks that will be used when analyzing samples for this project are:

Chemical:

X	Reagent Blanks	X	Matrix Spikes
X	Duplicate Samples	X	QC Check Samples
X	Duplicate Matrix Spikes	X	QC Check Standards
X	Continuing Calibration Stnds		
X	Other: Biomass: Calibration Weights		

Microbiology: Not applicable

____	Duplicates	____	Control Blanks (MF)
____	Carry over blanks (MF)	____	Dilution Blanks (MPN)
____	Positive & Negative Controls		
____	Other:_____		

Section 5.0C **LABORATORY PROCEDURES AND QUALITY CONTROL**

The laboratory analyses shall be conducted by ENCO Laboratories (TOC, see Exhibit 3.2C).

The Comprehensive QA Plan number for this organization is 910190.

The date of the last update approval is November 3, 2000.

All protocols, procedures and policies in the above-referenced document that are pertinent to this Quality Assurance Project Plan shall be followed. The laboratory shall analyze the samples for this project by the methods specified in Table 3.2 of the QAPP.

5.1 **Quality Control Checks**

The types of laboratory control checks that will be used when analyzing samples for this project are:

Chemical:

X	Reagent Blanks	X	Matrix Spikes
X	Duplicate Samples	X	QC Check Samples
X	Duplicate Matrix Spikes	X	QC Check Standards
X	Continuing Calibration Stnds		
__	Other: _____		

Microbiology: Not applicable

____	Duplicates	____	Control Blanks (MF)
____	Carry over blanks (MF)	____	Dilution Blanks (MPN)
____	Positive & Negative Controls		
____	Other:_____		

Section 5.0D **LABORATORY PROCEDURES AND QUALITY CONTROL**

The laboratory analyses shall be conducted by Law Engineering (Soil - Bulk Density, see Exhibit 3.2D)

The Comprehensive QA Plan number for this organization is 950024.

The date of the last update approval is March 24, 2000.

All protocols, procedures and policies in the above-referenced document that are pertinent to this Quality Assurance Project Plan shall be followed. The laboratory shall analyze the samples for this project by the methods specified in Table 3.2 of the QAPP.

5.1 **Quality Control Checks**

The types of laboratory control checks that will be used when analyzing samples for this project are:

Chemical:

___	Reagent Blanks	____	Matrix Spikes
___	Duplicate Samples	____	QC Check Samples
_._	Duplicate Matrix Spikes	____	QC Check Standards
_._	Continuing Calibration Stnds		
___	Other: _____		

Microbiology: Not applicable

____	Duplicates	____	Control Blanks (MF)
____	Carry over blanks (MF)	____	Dilution Blanks (MPN)
____	Positive & Negative Controls		
____	Other:_____		

Section 6.0 **QUALITY ASSURANCE MANAGEMENT**

6.1 **Corrective Actions**

In addition to corrective actions cited in the approved Comprehensive QA Plans, **ALL INVOLVED PARTIES WILL INITIATE ANY CORRECTIVE ACITON DEEMED NECESSARY BY DEP OR THE DISTRICT.**

6.2 **Performance and Systems Audits**

6.2.1 Field Activities

Specific audits planned for this project are*:* Field-sampling procedures are routinely reviewed and refined by the project senior scientist; no formal field audits are planned.

Audit Type	Frequency/Date	Description
1.		
2.		
3.		

6.2.2 Laboratory Activities

Specific audits planned for this project are: None

Audit Type	Frequency/Date	Description
1.		
2.		
3.		

ALL INVOLVED PARTIES WILL CONSENT TO AUDITS BY DEP IF DEEMED NECESSARY.

6.3 Quality Assurance Reports

Project specific QA Reports will be submitted to FDEP Quality Assurance Section at a frequency of one annual report at the end of Phase 2 of the PSTA project, if requested.

Note: Frequency must comply with Table V, Appendix D of the DEP Manual for Preparing Quality Assurance Plans or Table 6 of Chapter 62-160, F.A.C., Quality Assurance.

Attachment A

Executive Summary

PSTA Research and Demonstration Project
Phase I Summary Report

Executive Summary

Introduction

The South Florida Water Management District (District) is conducting research focused on determining the effectiveness and design criteria of potential advanced treatment technologies to support reduction of phosphorus (P) loads in surface waters entering the remaining Everglades (SFWMD, 2000). Particular focus is being placed on the treatment of surface waters from the Everglades Agricultural Area (EAA) as well as Lake Okeechobee water that is diverted through the primary canal system to the Lower East Coast of Florida.

Periphyton-based stormwater treatment areas (PSTAs) are one of the advanced treatment technologies being researched by the District for potential application downstream of the macrophyte-based stormwater treatment areas (STAs). The PSTA concept was proposed for P removal from EAA waters by Doren and Jones (1996) and further described and evaluated by Kadlec (1996a) and Kadlec and Walker (1996). Because of the nutrient intolerance of periphyton, evaluations remain focused on PSTAs as post-STA treatment units intended to help achieve compliance with the anticipated ultimate total phosphorus (TP) criterion of 10 parts per billion (ppb) or less.

In concept, the periphyton complex is hypothesized as being capable of extraction of available phosphorus in the water introduced into the system and incorporation of that phosphorus into the biomass of the periphyton mat. Settling of detrital matter contributes to the long-term phosphorus storage. Additionally, because of the high primary productivity of these periphyton systems, water quality conditions favor phosphorus precipitation and binding into the newly formed sediments. The result is a water outflow with much of the available phosphorus scavenged and retained in the system. These concepts are depicted in Exhibit ES-1.

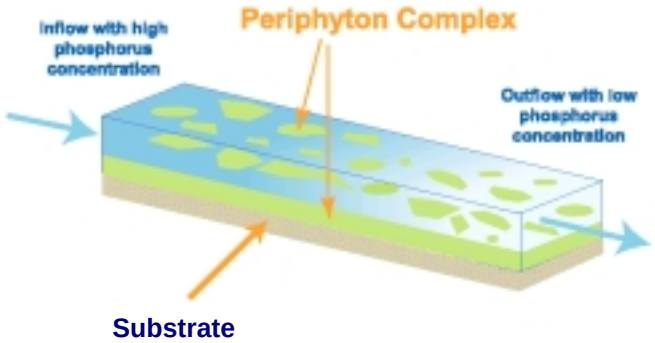


EXHIBIT ES-1
Schematic Diagram of the Periphyton Stormwater Treatment Area (PSTA) Concept

Prior to initiation of the District's PSTA project in July 1998, detailed research to evaluate PSTA feasibility had not been performed. The overall objectives of the study were to determine:

- If PSTA systems could be constructed (viability),
- If such constructed wetlands could achieve the level of phosphorus reduction desired (effectiveness) and if so,
- Whether the treatment performance could be sustained for long time periods allowing cost-effective integration of PSTAs with other treatment technologies (sustainability).

A two-phased approach was adopted to address the stated objectives of the PSTA concept evaluation: an Experimental Phase (Phase 1), and a Validation / Optimization Phase (Phase 2). The two phases, and the types of activities that are included in each, are described as follows:

- **Phase 1 (Experimental Phase)** included development of the work plan and experimental design, initial research in three experimental test cells (PSTA Test Cells) located at the southern end of the Everglades Nutrient Removal (ENR) project (see Exhibit ES-2 and SFWMD 2000 for location of sites), and construction and startup / monitoring of research using 24 portable experimental mesocosms (Porta-PSTAs). The Phase 1 experimental studies have yielded critical information needed to plan for field-scale mesocosm (Field PSTAs) design and construction in Phase 2. Development of a forecast model and associated predictive tools has occurred, along with preliminary model calibration with the Phase 1 experimental data.

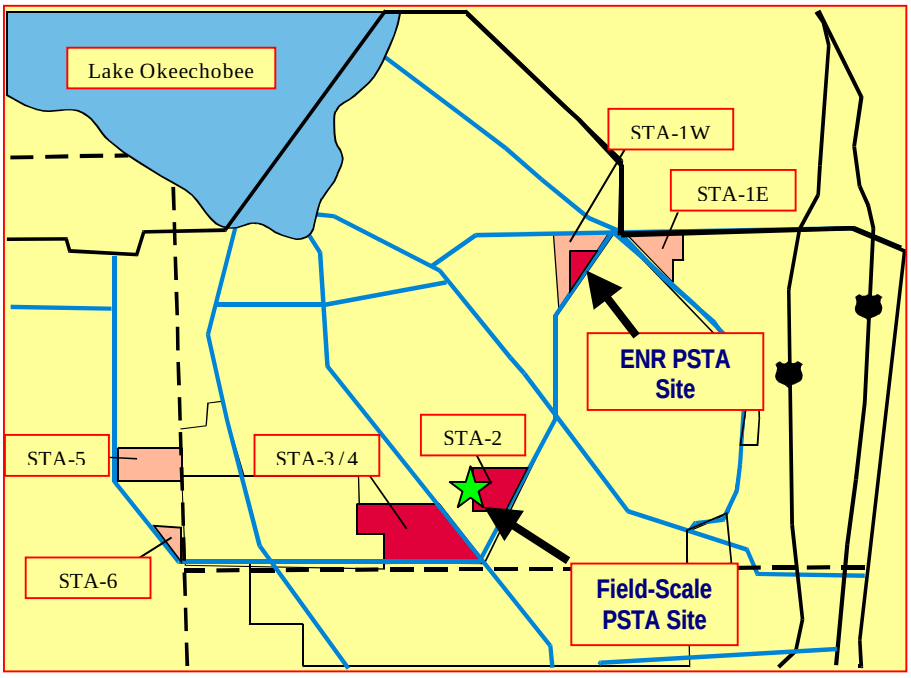


EXHIBIT ES-2
Locations of District PSTA Research Sites

- **Phase 2 (Validation/Optimization Phase)** will include continued research in the ENR PSTA Test Cells and in the Porta-PSTAs, and new studies at the field-scale pilot PSTAs under construction immediately west of STA 2. During Phase 2, the expanded database will be used to validate the performance forecast model, and develop design criteria for a full-scale PSTA system. The forecast model will be applied to provide projections of the long-term cost of implementing PSTAs to meet ultimate P reduction goals under the Everglades Forever Act (EFA).

In the aggregate, the PSTA Research and Demonstration Project is designed to develop defensible conclusions related to specific hypotheses that are relevant to key research questions and design issues described in the *PSTA Research Plan* (CH2M HILL, 1999). This report provides a summary of the Phase 1 findings.

Experimental Mesocosm Design

Exhibit ES-3 provides a summary of the treatments used for Phase 1 of the PSTA Research and Demonstration Project. A more detailed description of the two mesocosm scales is provided in the following sections and in Appendices B and C.

EXHIBIT ES-3
PSTA Phase 1 Design Criteria and Experimental Treatments

Treatment	Cells	Area (m^2)	Soil Type	Water Depth (cm)	HLR (cm/d)	Depth:Width Ratio	Other Considerations
PP-1	9, 11, 18	6	peat	60	6	0.6	Macrophytes
PP-2	4, 7, 8	6	shellrock	60	6	0.6	Macrophytes
PP-3	12, 14, 17	6	peat	30	6	0.3	Macrophytes
PP-4	3, 5, 10	6	shellrock	30	6	0.3	Macrophytes
PP-5	2, 13, 16	6	shellrock	60	12	0.6	Macrophytes
PP-6	1, 6, 15	6	shellrock	0-60	0-12	0-0.6	Macrophytes
PP-7	19	6	sand	30	6	0.3	Macrophytes
PP-8	20	6	sand	60	6	0.6	Macrophytes
PP-9	21	6	peat	60	6	0.6	Aquashade; no macrophytes
PP-10	22	6	shellrock	60	6	0.6	Aquashade; no macrophytes
PP-11	23	18	shellrock	30	6	0.1	Macrophytes
PP-12	24	18	peat	30	6	0.1	Macrophytes
STC-1	13	2,240	peat	60	6	0.0214	Macrophytes
STC-2	8	2,240	shellrock	60	6	0.0214	Macrophytes
STC-3	3	2,240	shellrock	0-60	0-12	0-0.0214	Macrophytes

South ENR Test Cells

The South ENR Test Cells (STC) consist of 15 rectangular, 0.2-hectare (ha) cells receiving flows from a single Head Cell. Water pumped into the Head Cell from the ENR Cell 3 flows by gravity through a distribution manifold into each of the Test Cells. The District assigned three ENR Test Cells to the PSTA Research Project. During final construction, substrate within these PSTA Test Cells was modified by the District by placing the following layers of substrate over the cell liner:

- **STC-1 (Test Cell 13**) – approximately 80 centimeters (cm) of sand surcharge plus 30 cm of locally-mined shellrock plus 30 cm of peat taken from a local, unflooded, and former agricultural lands area

- **STC-2 (Test Cell 8)** – approximately 1 meter of sand surcharge plus 30 cm of locally-mined shellrock
- **STC-3 (Test Cell 3)** – approximately 1 meter of sand surcharge plus 30 cm of locally-mined shellrock

Exhibit ES-4 shows PSTA Test Cell 8 (PSTA Treatment STC-2), with shellrock substrate after nearly 1 year of colonization.

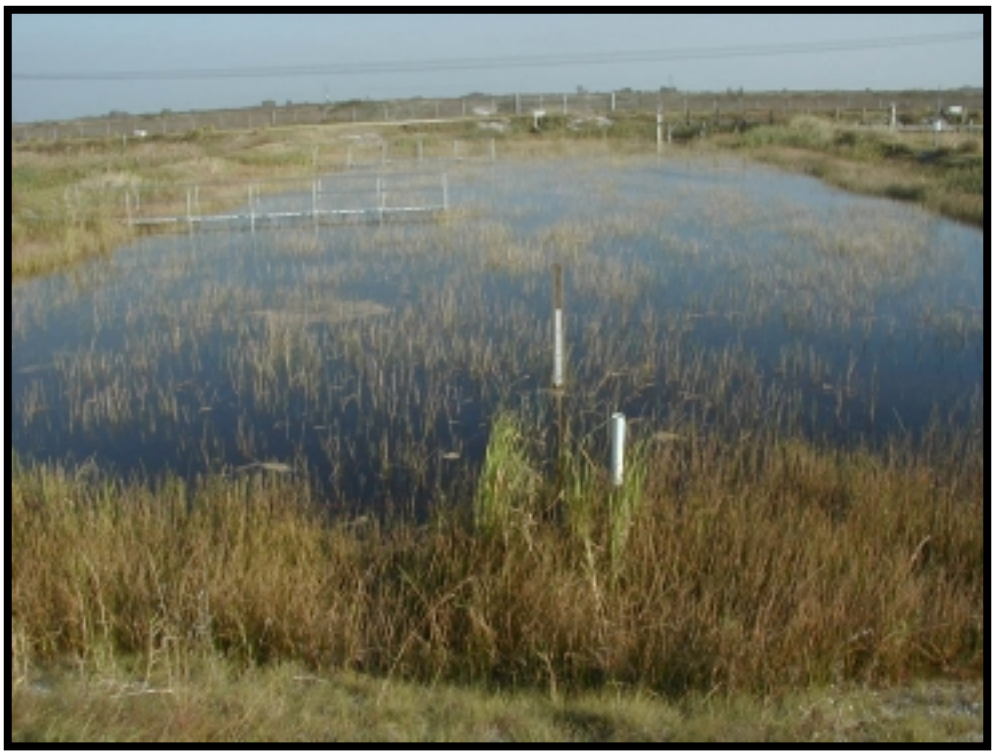


EXHIBIT ES-4
PSTA Test Cell 8 (Treatment STC-2) After Approximately 12 Months of Colonization
This photo is looking upstream from the outfall standpipes toward the inflow at the far end of the cell. Monitoring walkways are located at 1/3 and 2/3 points along the flow path.

Porta-PSTA Mesocosms

Twenty-four Porta-PSTA mesocosm units were fabricated of fiberglass offsite and delivered to the South ENR Supplemental Technology Research Compound. Twenty-two of the fiber-glass tanks are 6 meters long by 1 meter wide by 1 meter deep. The remaining two tanks are 3 meters wide to allow assessment of mesocosm configuration effects. Exhibit ES-5 shows the layout of typical 1- and 3-meter-wide mesocosms in relation to the constant-head tank and inlet manifolds.

Porta-PSTA treatments focused on the following primary design variables:

- Substrate type – either organic soils (peat) or shellrock
- Water depth
- Hydraulic loading rate (HLR)

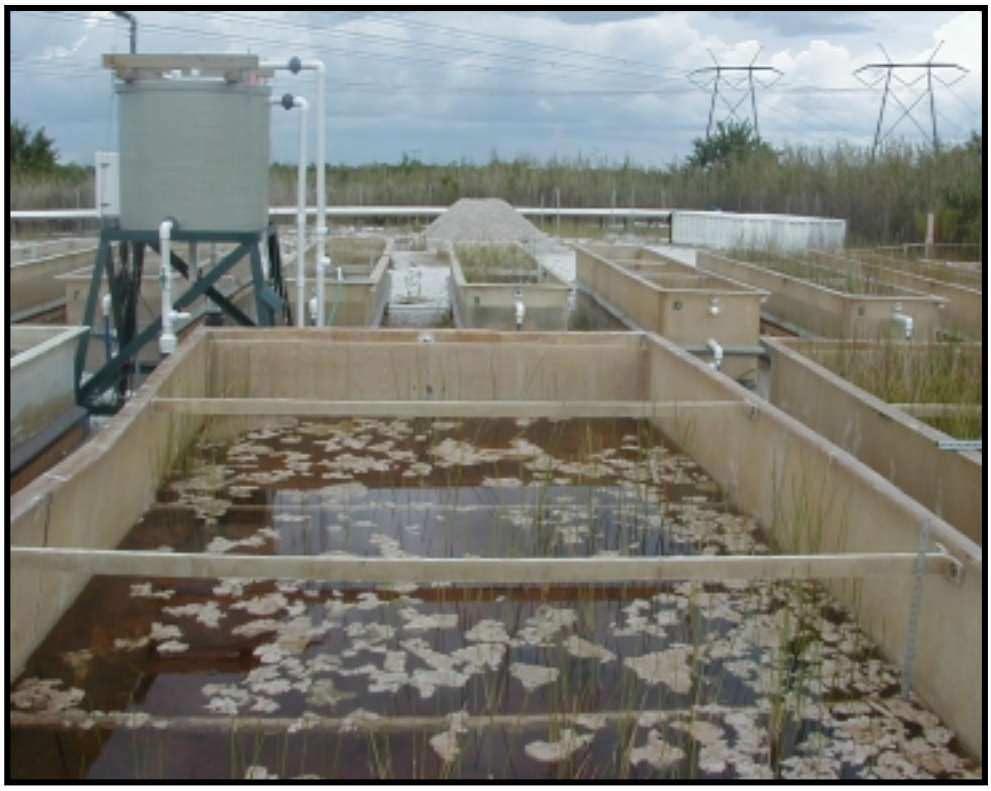


EXHIBIT ES-5
Porta-PSTA Tank 23 (Treatment PP-11) After 11 Months of Colonization
This 6 x 3 meter tank has shellrock soils and was operated at a 30-cm water depth. Floating periphyton mats are visible among the sparse emergent macrophytes. Narrow tanks can be seen in the background as well as the constant Head Tank used to feed all mesocosms at this site.

Substrate and water depth were replicated in a complete factorial design while hydraulic loading was only varied on the shellrock substrate. All Porta-PSTA treatments were planted with an initial low density of emergent macrophytes.

In addition to these primary treatment variables, these smaller PSTA mesocosms were also screened for effects of:

- Scale (l x 6 meter vs. 3 x 6 meter)
- Sand substrate (relatively inert with respect to oxygen demand and total P content)
- Unvegetated controls with Aquashade (aquatic dye) to reduce periphyton growth

Phase 1 Experimental Results

As outlined previously, the key research questions related to the PSTA concept have to do with viability, effectiveness, and sustainability:

- Viability: Can periphyton-dominated ecosystems for P control be established?
- Effectiveness: Can P removal and retention be achieved?
- Sustainability: Can PSTA viability and effectiveness be maintained for the long-term?

Phase 1 research dealt primarily with the issues of viability and effectiveness. Viability was assessed by the observed growth of periphyton-dominated plant communities in the PSTA mesocosms. Effectiveness was evaluated based on the ability of the PSTA test systems to achieve low TP outflow concentrations and by estimating the TP removal rate constant that ultimately determines the necessary footprint to implement the PSTA concept.

Plant Community Establishment

A total of 361 algal taxa were identified in the PSTA periphyton samples. Exhibit ES-6 provides a summary of the dominant species (defined as those that most frequently comprised more than 10 percent of the cell count or biovolume totals). Filamentous green algae were observed to occupy the front end of the mesocosms in areas of measurable dissolved reactive P (DRP), while filamentous blue-greens and diatoms dominated floating and benthic periphyton mats throughout the majority of the test systems.

Ash-free dry weight biomass increased to sustainable levels (typically between 100 and 600 grams per square meter [g/m^2] in all mesocosms and Test Cells) within 1 to 2 months from startup. Chlorophyll *a* (corrected for pheophytin) and algal biovolume continued to increase throughout the study period. Average chlorophyll *a* concentrations were between 40 and 200 milligrams per square meter (mg/m^2).

Eleocharis cellulosa (spikerush) and *Utricularia* spp. (bladderwort) were purposely added to most of the PSTA mesocosms. Natural Everglades periphyton-dominated plant communities include these macrophytes and it was decided to include them in the test mesocosms because of their ability to add periphyton attachment sites and stability against wind-induced periphyton mobility. *Typha latifolia* (cattail), *Hydrilla verticillata* (hydrilla), and *Chara* spp. (stonewort) invaded some of the PSTA mesocosms. Macrophyte biomass estimates indicated that the peat soil mesocosms were overwhelmed by macrophyte growth (see Exhibits ES-7 and ES-8), dominating visual plant cover estimates. Nevertheless, macrophyte cover dominance did not appear to limit the periphyton community importance in peat-based mesocosms as measured by chlorophyll *a* and algal biovolume.

Inflow Phosphorus Concentrations

Inlet P concentrations were variable throughout the project period (see Exhibits ES-9 and ES-10). While mean TP concentrations were similar at the Porta-PSTA and Test Cell sites (23 micrograms per liter [µg/L]), TP concentrations were greater at the Test Cells during late summer and higher at the Porta-PSTAs during the early spring and late winter. These differences in TP were largely attributable to complex seasonal variations in the concentrations of total dissolved P (TDP) and total particulate P (TPP) in the two water supplies. On the average, TDP comprised 52 and 70 percent of TP at the Test Cells and Porta-PSTAs, respectively. DRP was approximately 5 and 6 µg/L, respectively, while dissolved organic P (DOP) averaged 7 and 11 µg/L in the inflow waters, respectively.

EXHIBIT ES-6

Dominant Algal Species in PSTA Mesocosms During Phase 1

Principal algal groups on all substrates were blue-greens and diatoms.

		Percent of Samples > 10% of Total		Long-Term Averages	
				Cell Counts	Biovolumes
Taxon	Phylum	Cell Counts	Biovolumes	(# cells/m^2)*10^6	(cm^3/m^2)
MASTOGLOIA SMITHII	Bacillariophyceae		26.3%	861	2.994
LYNGBYA LIMNETICA	Cyanobacteria	15.9%	5.2%	65617	1.640
OSCILLATORIA ANGUSTISSIMA	Cyanobacteria	14.8%		19043	0.038
OSCILLATORIA LIMNETICA	Cyanobacteria	13.7%		46492	0.325
RHOPALODIA GIBBA	Bacillariophyceae		10.4%	87	2.197
SCYTONEMA SP?	Cyanobacteria	1.1%	7.8%	6650	9.211
LYNGBYA LAGERHEIMII	Cyanobacteria	7.4%		14333	0.086
MASTOGLOIA SMITHII V LACUSTRIS	Bacillariophyceae		7.4%	765	1.229
CYLINDROSPERMUM SP	Cyanobacteria	5.9%	0.7%	7355	0.299
APHANOTHECE STAGNINA	Cyanobacteria	4.4%	0.7%	12988	0.312
OEDOGONIUM PUNCTATOSTRIATUM	Chlorophyta	0.4%	4.4%	237	1.905
OSCILLATORIA FORMOSA	Cyanobacteria	3.3%	1.5%	8893	0.703
APHANOCAPSA DELICATISSIMA	Cyanobacteria	4.1%		7787	0.008
MASTOGLOIA LANCEOLATA	Bacillariophyceae		3.7%	154	1.036
JOHANNESBAPTISTIA PELLUCIDA	Cyanobacteria	2.6%	0.7%	2922	0.164
APHANOTHECE SMITHII	Cyanobacteria	3.0%		7466	0.044
AMPHORA LINEOLATA?	Bacillariophyceae		2.6%	111	0.606
LYNGBYA SP (SMALL)	Cyanobacteria	2.6%		11604	0.058
NITZSCHIA SEMIROBUSTA	Bacillariophyceae		2.6%	382	0.225
OSCILLATORIA PRINCEPS	Cyanobacteria		2.6%	860	5.401
SCHIZOTHRIX ARENARIA?	Cyanobacteria	2.6%		29670	0.386
EUGLENA SP	Cyanobacteria0		2.2%	53	0.685
OEDOGONIUM SP	Chlorophyta	0.4%	1.9%	344	0.691
CHROOCOCCUS MINIMUS	Cyanobacteria	1.9%		4229	0.017
GYROSIGMA OBSCURUM?	Bacillariophyceae		1.9%	27	0.235
MICROCYSTIS FIRMA	Cyanobacteria	1.9%		3072	0.025
NITZSCHIA SERPENTIRAPHE	Bacillariophyceae		1.9%	112	1.041
OSCILLATORIA SP (SMALL)	Cyanobacteria	1.9%		6304	0.031
OSCILLATORIA LIMNETICA?	Cyanobacteria	1.5%		7586	0.053
OSCILLATORIA LIMOSA	Cyanobacteria		1.5%	2507	0.998
PINNULARIA VIRIDIS	Bacillariophyceae		1.5%	13	1.107
SPIROGYRA SP	Chlorophyta		1.5%	24	2.180
UNID FILAMENTOUS CHLOROPHYTA	Chlorophyta		1.5%	725	0.582
GOMPHOSPHAERIA APONINA	Cyanobacteria	1.1%		1581	0.044
OSCILLATORIA AMPHIBIA	Cyanobacteria	0.7%	0.4%	5347	0.342
PINNULARIA RUTTNERI	Bacillariophyceae		1.1%	27	1.186
RHABDODERMA LINEARE?	Cyanobacteria	1.1%		4277	0.192
APHANOCAPSA CONFERTA	Cyanobacteria	0.7%		4109	0.016
APHANOTHECE STAGNINA?	Cyanobacteria	0.7%		2912	0.070
CHROOCOCCUS DISPERSUS	Cyanobacteria	0.7%		3637	0.051
ENCYONEMA EVERGLADIANUM	Bacillariophyceae	0.7%		1165	0.219
FRAGILARIA FASCICULATA?	Bacillariophyceae		0.7%	75	0.139
LYNGBYA AESTUARII	Cyanobacteria	0.4%	0.4%	1044	0.277
LYNGBYA EPIPHYTICA	Cyanobacteria	0.7%		9984	0.060
LYNGBYA LIMNETICA?	Cyanobacteria	0.7%		5329	0.133
NITZSCHIA SIGMOIDEA	Bacillariophyceae		0.7%	7	2.599
PLAGIOTROPIS LEPIDOPTERA	Bacillariophyceae		0.7%	8	0.152
SPHAEROCYSTIS SCHROERTERI	Chlorophyta		0.7%	2031	0.230
APHANOCAPSA GREVILLEI	Cyanobacteria	0.4%		1296	0.084
CHROOCOCCUS SP	Cyanobacteria		0.4%	766	0.427
CLOSTERIUM ACEROSUM	Chlorophyta		0.4%	0	0.360
CLOSTERIUM LUNULA V MASSARTII	Chlorophyta		0.4%	1	0.319
COSCINODISCUS GRANII	Bacillariophyceae		0.4%	10	3.444
CYMBELLA ASPERA	Bacillariophyceae		0.4%	1	0.052
DIPLONEIS SMITHII	Bacillariophyceae		0.4%	16	0.787
FRAGILARIA ULNA	Bacillariophyceae		0.4%	25	0.291
GLOEOCAPSA SP	Cyanobacteria	0.4%		1999	0.008
GOMPHOSPHAERIA SP	Cyanobacteria	0.4%		180	0.012
GYROSIGMA NODIFERUM	Bacillariophyceae		0.4%	10	0.051
LEMMERMANNIELLA PALLIDA	Cyanobacteria	0.4%		2173	0.013
LYNGBYA AERUGINEO-CARULEA?	Cyanobacteria		0.4%	5713	0.674
MERISMOPEDIA GLAUCA	Cyanobacteria	0.4%		1268	0.018
MICROCYSTIS AERUGINOSA	Cyanobacteria	0.4%		3053	0.104
NITZSCHIA SERIATA	Bacillariophyceae		0.4%	26	0.044
OOCYSTIS SOLITARIA	Chlorophyta		0.4%	102	0.138
OSCILLATORIA SP	Cyanobacteria	0.4%		1137	0.028
SCYTONEMA HOFMANII?	Cyanobacteria	0.4%		2047	0.153
STAURASTRUM CYCLACANTHUM	Chlorophyta		0.4%	5	0.107
SURIRELLA ELEGANS	Bacillariophyceae		0.4%	1	0.152

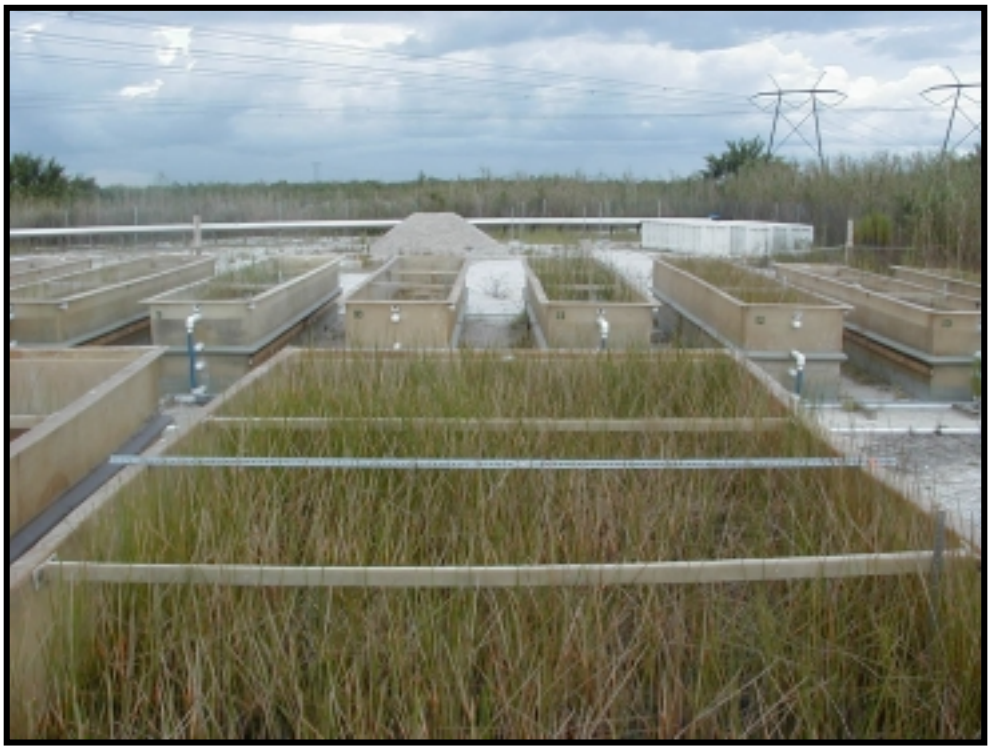


EXHIBIT ES-7
Photograph of PP-12 (Tank 24) Showing Dense Colonization by Spikerush
Average live stem count in this tank was approximately 300 stems/m^2 by the end of Phase 1. Periphyton biomass and algal cell counts remained high, even with macrophyte cover.

Phosphorus Removal Performance

Exhibit ES-11 summarizes the TP concentrations and estimated k-C* model parameters for each treatment during the post-startup period-of-record. Values for k_1 are also summarized in Exhibit ES-11 and offer a normalized comparison between treatments.

P removal rate constants generally increased through the period of the Phase 1 PSTA research (see Exhibit ES-12). An initial startup period is evident in the data during the first 3 to 5 months of system operation, followed by apparent seasonal patterns in the semi-mature PSTA mesocosms.

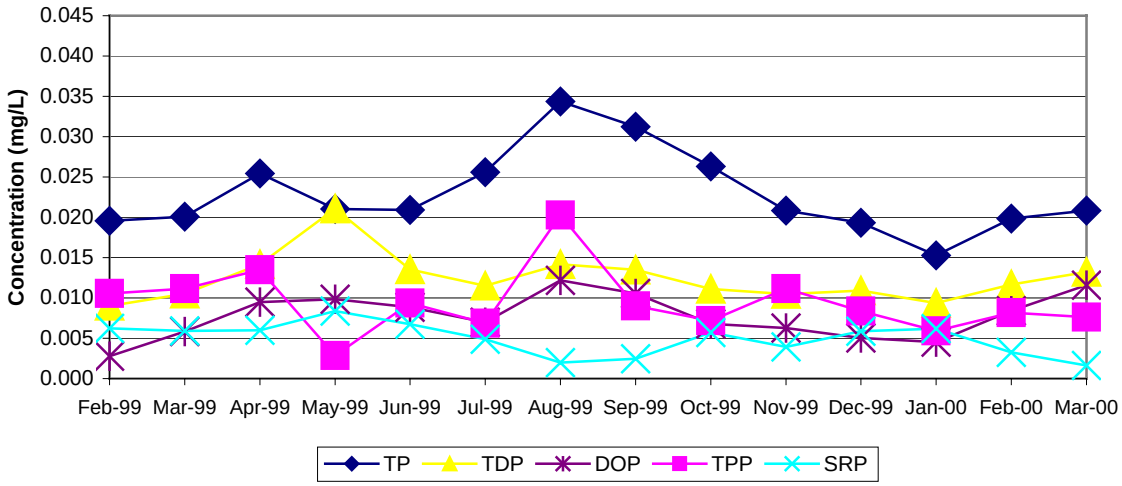


EXHIBIT ES-9
Temporal Pattern of Inflow P Concentrations to the PSTA Test Cells During Phase 1

EXHIBIT ES-8
Average Total Macrophyte Biomass in the PSTA Mesocosms During Phase 1

Treatment	Soil Type	Biomass (g dw/m^2)
PP-1	Peat	75.1
PP-2	Shellrock	19.4
PP-3	Peat	214.8
PP-4	Shellrock	21.5
PP-5	Shellrock	26.0
PP-6	Shellrock	13.7
PP-7	Sand	0.0
PP-8	Sand	3.4
PP-9	Peat	0.0
PP10	Shellrock	0.0
PP-11	Shellrock	88.5
PP-12	Peat	176.2
TC-1	Peat	582.1
TC-2	Shellrock	60.9
TC-3	Shellrock	55.4

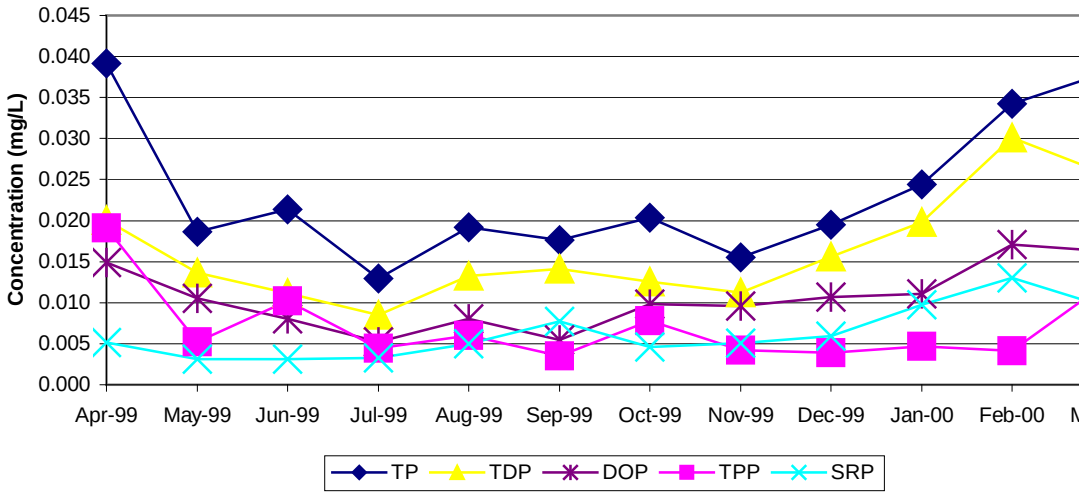
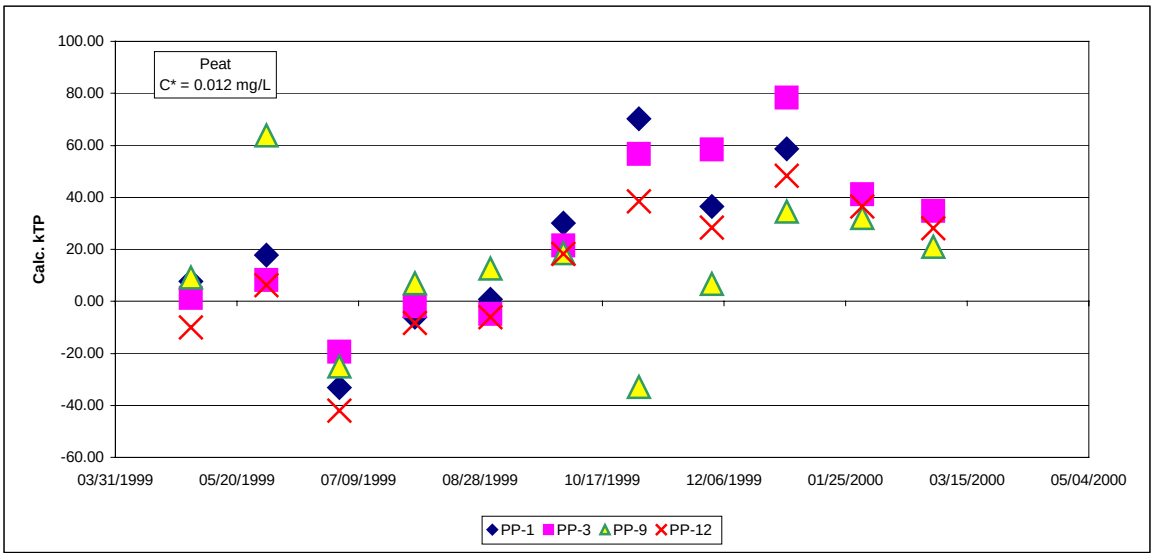


EXHIBIT ES-10
Temporal Pattern of Inflow P Concentrations to the Porta-PSTA Mesocosms During Phase 1

EXHIBIT ES-11
Average Performance and Estimated Parameters for the k_1 and k-C* Models from the PSTA Phase 1 Mesocosm Research

Treatment	Soil Type	Water Depth (cm)	Average TP (mg/L)		HLR (m/yr)	k_1 (m/yr)	k (m/yr)	C* (mg/L)
			In	Out				
PP-1	Peat	60	0.020	0.014	34.9	11.23	25.8	0.009
PP-2	Shellrock	60	0.020	0.013	33.4	13.91	39.1	0.010
PP-3	Peat	30	0.025	0.015	31.9	15.69	32.7	0.010
PP-4	Shellrock	30	0.025	0.014	32.5	18.12	33.4	0.009
PP-5	Shellrock	60	0.025	0.017	62.8	27.01	68.1	0.013
PP-6	Shellrock	0-60	0.026	0.015	16.5	9.06	23.4	0.010
PP-7	Sand	30	0.025	0.015	31.4	16.20	41.7	0.012
PP-8	Sand	60	0.020	0.016	33.9	7.84	89.3	0.015
PP-9	Peat	60	0.026	0.020	34.9	8.16	35.5	0.012
PP-10	Shellrock	60	0.026	0.015	32.4	17.73	45.4	0.012
PP-11	Shellrock	30	0.025	0.016	32.5	14.94	34.0	0.012
PP-12	Peat	30	0.025	0.017	32.7	13.16	36.2	0.013
STC-1	Peat	60	0.025	0.016	16.5	6.94	16.6	0.012
STC-2	Shellrock	60	0.024	0.013	16.9	9.58	26.3	0.011
STC-3	Shellrock	0-60	0.023	0.018	17.0	4.30	14.5	0.013

Notes:
Data are for the period-of-record after the end of startup. C* is set equal to the lowest observed monthly average. The k_1 values are post startup averages and assume C*=0. The k values are estimated by the Excel Solver routine to minimize the difference between observed and estimated monthly average outflow TP concentrations.



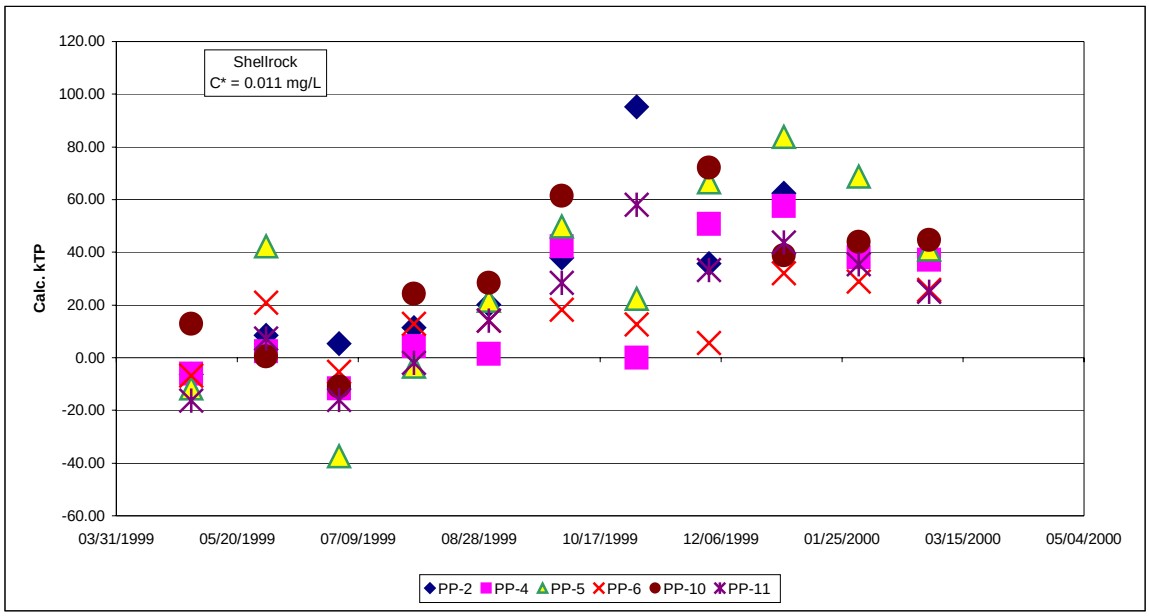


EXHIBIT ES-12
Pattern of Monthly Average TP k Values Measured in the Porta-PSTAs During Phase 1

The following conclusions concerning effectiveness were drawn from these Phase 1 research data:

- Estimated values for C*, the effective background TP concentration resulting from internal and external loadings and removals, ranged from 9 to 15 µg/L
- Estimated TP k values ranged from 14.5 to 89.3 meters per year (m/y)
- Lowest post-startup treatment average TP outflow concentrations were 13 µg/L, and lowest treatment monthly averages were 9 µg/L
- Average TP k_1 values ranged from 4.3 to 27.0 m/y

- There were no consistent effects of water depth (30- vs. 60-cm steady depth) on outflow TP concentration; however, higher TP k_1 values were recorded in mesocosms with shallower depths
- Variable water depths resulted in reduced TP removal performance compared to stable water depths
- Outflow TP concentrations were lower and k_1 values higher in mesocosms built with shellrock substrates than in comparable mesocosms with peat soils (see Exhibit ES-13)
- Higher loading rates (hydraulic and TP mass) increased k_1 and average outflow TP concentration
- A mesocosm scale effect was observed that indicated that smaller mesocosms underestimated outflow TP values by 0 to 14 percent and overestimated k_1 values by 16 to 38 percent
- In Aquashade control mesocosms, average outflow TP concentrations were higher but k_1 values were not consistently higher or lower than vegetated treatments

EXHIBIT ES-13
Effects of Soil Type on Average TP Outflow Concentration and k_1 During the Post-startup Phase 1

Treatment	Soil	TP Out (mg/L)	k_1 (m/yr)
PP-1	Peat	0.014	11.2
PP-2	Shellrock	0.013	13.9
PP-8	Sand	0.016	7.8
PP-3	Peat	0.015	15.7
PP-4	Shellrock	0.014	18.1
PP-7	Sand	0.015	16.2
STC-1	Peat	0.016	6.9
STC-2	Shellrock	0.013	9.6

Note: Each group of treatments is identical except for soil type.

Phosphorus Dynamics and Fate

The Phase 1 PSTA research offers a variety of "clues" to the processes that are important in P retention in periphyton-dominated treatment units. While this research has focused on the overall input-output of TP, specific processes that have been studied include: the fate of P in the mesocosm soils, observed non-reactive P forms, gross P accretion rates, and the effects of snail grazing on P dynamics.

The soils represent the largest single P storage in the PSTA mesocosms and in a full-scale PSTA. The reactivity of P in antecedent soils greatly affects the startup performance of a PSTA (as well as other "natural" technologies, such as emergent macrophyte and submerged aquatic vegetation [SAV]-dominated STAs). The PSTA research observed a declin-

ing concentration of TP in peat soils during the first few months of flooding. Inorganic dissolved reactive forms of P were initially released from these soils. In addition, subsequent tests indicated that P continued to be released from these soils, probably through oxidation of soils in the relatively aerobic algal-dominated environment. P was also released from shellrock and sand soils, but at a lower rate.

Net P accretion was assessed with sedimentation "traps". These shallow containers were placed on the soil surface for approximately 60 to 90 days. Average net dry matter and TP accretion rates during this period were greater in shellrock mesocosms than in peat- or sand-based systems (see Exhibit ES-14). The overall average dry matter accretion rate was 919 $g/m^2/y$ with 0.59 g TP $/ m^2 / y$ of which approximately 10 percent can be assumed to be non-reactive organic P (based on separate periphyton mat measurements). A large fraction of this dry matter is ash, including the majority of the inorganic P that consists of calcium-bound P forms.

EXHIBIT ES-14
Sediment Trap Data from the Porta-PSTA Mesocosms During Phase 1 (July - October 1999 and November 1999 - February 2000)

Treatment	Wet Accretion (cm/y)	Wet Accretion ($mL/m^2/y$)	Dry Accretion ($g/m^2/y$)	TP Accretion ($g/m^2/y$)	Wet Bulk Density (g/cm^3)	Dry Bulk Density (g/cm^3)	TP (mg/kg)	Ash (%)
all	1.49	14944	919	0.59	0.90	0.050	644	62
peat	0.78	7775	242	0.14	0.93	0.029	653	38
sand	0.82	8164	962	0.04	0.95	0.069	236	81
shell	2.05	20497	1358	0.95	0.88	0.060	693	73
PP-1	0.96	9553	390	0.19	1.00	0.039	484	43
PP-2	1.46	14582	493	0.22	0.89	0.039	596	64
PP-3	0.66	6629	155	0.10	0.91	0.024	621	33
PP-4	4.05	40472	4230	3.13	0.90	0.100	786	84
PP-5	1.45	14477	512	0.32	0.90	0.041	688	64
PP-6	0.94	9396	552	0.36	0.86	0.070	725	72
PP-7	1.48	14788	1858	0.06	1.03	0.096	19	84
PP-8	0.15	1540	67	0.03	0.87	0.043	454	78
PP-9	0.49	4852	217	0.17	1.00	0.049	770	47
PP-10	1.49	14927	219	0.20	0.61	0.015	908	70
PP-11	3.08	30829	1829	1.37	0.95	0.067	555	83
PP-12	0.77	7686	111	0.07	0.83	0.014	897	28

Note: Gross accretion rates were estimated in 14-cm-diameter plastic traps for a 2- to 3-month period. Values are averages of all replicates within a treatment.

Snails became the dominant grazer in some of the smaller PSTA mesocosms. Snail density was stochastic with no apparent relation to any of the treatment variables. High snail densities were linked to higher TP outflow concentrations and reduced removal rate constants apparently because of grazing effects on the periphyton mat. It is hypothesized that snail densities were kept in check in the larger PSTA Test Cell mesocosms by natural predators, such as fish and birds.

PSTA Forecast Model Development

The PSTA concept is being tested within a relatively short schedule dictated by law. Modeling of the key processes will allow estimation of future performance and operational costs.

Methods for forecasting PSTA operation and performance range in complexity from single- to multiple-parameter models. One- and two-parameter model calibration results were presented previously (K_1 and K-C* models). In addition, a "Level 2" PSTA Model has been proposed and partially calibrated to provide a more compete and mechanistic method for performance forecasting. This model will be refined further during Phase 2.

A model of intermediate complexity has recently been developed to allow design of advanced treatment technologies that are subject to variable flows (Walker and Kadlec, 2000). It is currently anticipated that this "Dynamic Model for Stormwater Treatment Areas" (DMSTA) Model may be calibrated for PSTAs during Phase 2 of this project.

PSTA Phase 2 Research and Demonstration

Preliminary promising results from the PSTA Phase 1 project led to implementation of Phase 2 research and demonstration efforts in early 2000. Phase 1 findings and review and input by the PSTA Scientific Review Panel resulted in specific treatment and design changes during Phase 2, as well as continuing work with the most promising Phase 1 PSTA treatments. Possible obstacles to full-scale PSTA implementation that were identified in Phase 1 include:

- Monthly average TP outflow concentrations of less than 9 µg/L were not obtained on peat, shellrock, or sand soils within a 1-year period
- Emergent macrophyte density overwhelmed periphyton dominance on peat soils
- Fluctuating water levels and inflow rates lowered PSTA system performance
- The presence of abnormally high numbers of snail grazers within some of the small mesocosms reduced PSTA effectiveness

The Phase 2 research and demonstration plan was developed to address some of these key issues and to attempt to scale-up the PSTA concept to a realistic-sized treatment unit. Phase 2 changes include:

- Use of limerock soils in some Porta-PSTAs and at the field-scale pilot PSTAs to attempt to minimize the initial available soluble P, to maximize periphyton development rates and calcium availability, and to minimize macrophyte colonization rates
- Use of 30 cm as the average design depth to enhance periphyton growth and to raise P removal rates
- Tests of the effects of increased flow velocities on P uptake, periphyton growth, and periphyton P export at the Porta-PSTAs and field-scale pilot PSTAs
- Evaluation of complete dry-out in the PSTA Test Cells and Porta-PSTAs on P removal and periphyton community development

- Amending peat soils in a PSTA Test Cell and selected Porta-PSTAs with hydrated lime to see if labile P can be prevented from creating high initial water column P concentrations
- Testing of Porta-PSTA controls without any soils and with synthetic substrate

Some Porta-PSTA and Test Cell Phase 1 treatments were not altered, allowing an additional 6 to 12 months of monitoring for observation of seasonal trends. Other treatments were changed as described above and renumbered. Exhibit ES-15 provides a summary of the Phase 2 treatments at the three mesocosm research scales.

EXHIBIT ES-15
PSTA Phase 2 Treatments

Phase 2 Treatment	Substrate	Water Depth (cm)	Average Velocity (cm/s)	HLR (cm/d)	Area (m^2)	Width (m)	Length (m)
PP-13	PE-CA	30	0.0014	6	6	1	6
PP-14	LR	30	0.0014	6	6	1	6
PP-3	PE	30	0.0014	6	6	1	6
PP-4	SR	30	0.0014	6	6	1	6
PP-15	SR	30	0.5000	6	6	1	6
PP-16	SR	0-30	0.0014	0-12	6	1	6
PP-7	SA	30	0.0014	6	6	1	6
PP-17	SA-R	30	0.0014	6	6	1	6
PP-18	NS	30	0.0014	6	6	1	6
PP-19	SY	30	0.0014	6	6	1	6
PP-11	SR	30	0.0014	6	18	3	6
PP-12	PE	30	0.0014	6	18	3	6
STC-4	PE-CA	30	0.0185	6	2,240	28	80
STC-5	SR	30	0.0185	6	2,240	28	80
STC-6	SR	0-30	0.0185	0-12	2,240	28	80
FS-1	LR	30	0.0730	6	19,337	61	317
FS-2	LR	30	0.2200	6	19,971	21	951
FS-3	CR	30	0.0730	6	19,337	61	317

Notes:
PE = peat
PE-CA = peat amended with lime
LR = limerock
SA-R = sand rinsed with HCl
CR = caprock
SR = shellrock
SY = synthetic
SA = sand
NS = no substrate
PP = Porta-PSTA
STC = South Test Cell
FS = Field-Scale

Summary of PSTA Viability and Effectiveness

The periphyton communities that became established within the PSTA mesocosms attained biomass levels and replicated normal periphyton algal species assemblages typical of low-P Everglades waters (Browder et al., 1994) within the first year of operation. These plant communities display normal community-level responses (gross primary productivity and community respiration) to environmental forcing functions, such as sunlight and antecedent soil conditions. Based on the conditions selected for this research, these PSTA mesocosms were able to attain average TP outflow concentrations as low as 13 µg/L. These concentrations are considerably lower than the long-term average outflow TP concentration from the ENR of 22 µg/L (Walker, 1999) and are comparable to ENR Cell 4 averages during the past 2 years (13 to 15 µg/L) (DB Environmental Laboratories [DBEL], 2000).

Lower average TP outflow concentrations have been observed in natural periphyton-dominated communities in Water Conservation Area 2A (McCormick et al., 1996), in the southern Everglades, and in experimental mesocosms built with limerock soils (DBEL, 1999). The minimum TP values recorded during this Phase 1 research were clearly related to internal P loading from antecedent soils. It is not currently known if these minimum outflow TP concentrations will continue to decline with increasing system maturity and eventual complete burial of antecedent soils. Phase 2 PSTA research includes continued testing on shellrock soils and on calcium-amended peat soils, and testing on limerock soils at both small and large scales to determine which of these substrates results in lower achievable TP outflow concentrations.

The k_1 values recorded in this research are comparable to or higher than values recorded for emergent macrophyte and SAV-dominated treatment wetlands in South Florida. PSTA Phase 1 k_1 values were in the range of 10 to 27 m/y, depending on specific treatment variables. Walker (1999) determined that the overall ENR k_1 value was approximately 15.5 m/y for the period from March 1995 through November 1998. The k_1 value for Cell 3 of the ENR is probably most comparable because of similar inflow water quality conditions as the PSTA research sites. This cell averaged k_1 = 9.5 m/y during this operational period. Cell 4 of the ENR is dominated by SAV and averaged k_1 = 17.3 m/y during this same period. Continuing research with the PSTA mesocosms needs to be conducted to validate and refine the TP performance estimates obtained during the Phase 1 operational period.

APPENDIX B

PSTA Site Safety Plan

PSTA Site Safety Plan

Prepared for

South Florida Water Management District

May 2000

CH2MHILL
Deerfield Beach, Florida

Contents

Exhibits

Appendices

SECTION 1

Introduction

The purpose of this safety plan is to outline safety procedures and protocols required to conduct monitoring for the Periphyton-Based Stormwater Treatment (PSTA) project at the Everglades Nutrient Removal (ENR) project site (refer to Exhibit 1-1) and at the Field Scale Cells located within Storm Water Treatment Area (STA) 2 (refer to Exhibit 1-2). This safety plan provides minimum rules that all personnel must follow at the project site. Supplemental field safety instructions are provided in Appendix A.

1.1 Background

A safe workplace can only be achieved by the exercise of good judgment by responsible individuals. Good work practice requires mandatory safety rules and programs. Every worker has a responsibility to himself and his colleagues to plan and execute the required monitoring for the PSTA project safely.

This safety plan is designed to document the safety program that is in place to protect employees. Appropriate standards from the South Florida Water Management District Risk Management Division Administrative Policy and Procedure Manual are incorporated into this plan. The following sections of the District Manual will be available at each of the PSTA project trailers (located at the ENR and STA 2):

- Chemical Hygiene Plan
- Hazardous Communication Safety Program
- Hazardous Waste Safety Program

The safety plan incorporates applicable elements of the District's Chemical Hygiene Plan (CHP) and also addresses requirements of OSHA regulation 29 CFR 1910.1450. The following topics are covered by this safety plan:

- Designation of personnel responsible for implementation of the safety plan, including the assignment of a safety officer
- Site safety and access
- Control measures to reduce employee risk during monitoring activities

- Procedures to be used when working with potentially harmful chemicals and control measures to reduce employee exposure to chemicals including the use of personal protection equipment (PPE), and hygiene practices
- Procedures to be followed in the event of an emergency, including the location and proper use of available emergency equipment

1.2 Responsible Parties

1.2.1 Safety Officer

Fran Bennett/CH2M HILL will serve as the safety officer. The safety officer is responsible for the implementation of this safety plan. The safety officer will oversee monitoring activities, inspect the safe maintenance of the project trailer, and review and/or update the safety plan as necessary.

- Enforce the Site Safety Plan.
- Coordinate with the Project Manager to ensure that the required employee training and documentation takes place.
- Ensure that employees correctly use personal protective equipment when required.
- Ensure that personal protective equipment is properly maintained and is repaired or replaced as needed.
- Maintain the MSDS binder and appropriate correspondence.
- Keep the MSDS binder available to all employees
- Review new and revised MSDS with employees upon receipt and document this training in the employee's training log.
- Ensure that there is adequate storage for the chemicals.
- Report any chemical spills or employee exposures to the project manager.
- Communicate notices of contractor work at the ENR to the project team (i.e. blasting, road repairs, etc.)

1.2.2 Employees/Team Members

- Attend all training as scheduled.
- Immediately report any chemical spills to the safety officer.

- Immediately report any chemical exposures to the safety officer.
- Read and be familiar with the MSDS and other safety information contained in this Safety Plan.

1.3 Inspection Program

All employees and workers at the project site must practice safety awareness. It is not possible to design a set of rules to cover all possible hazards or accidents. Each person must carry out his/her work in the safest possible manner. Personnel should be familiar with the operation of emergency equipment.

Inspections shall be documented and will include the following:

- Each employee will inspect his/her work area daily.
- The safety officer will conduct weekly safety reviews
- The safety officer will inspect emergency equipment at least once per month.
- The project manager will review safety concerns with the safety officer on a monthly basis.

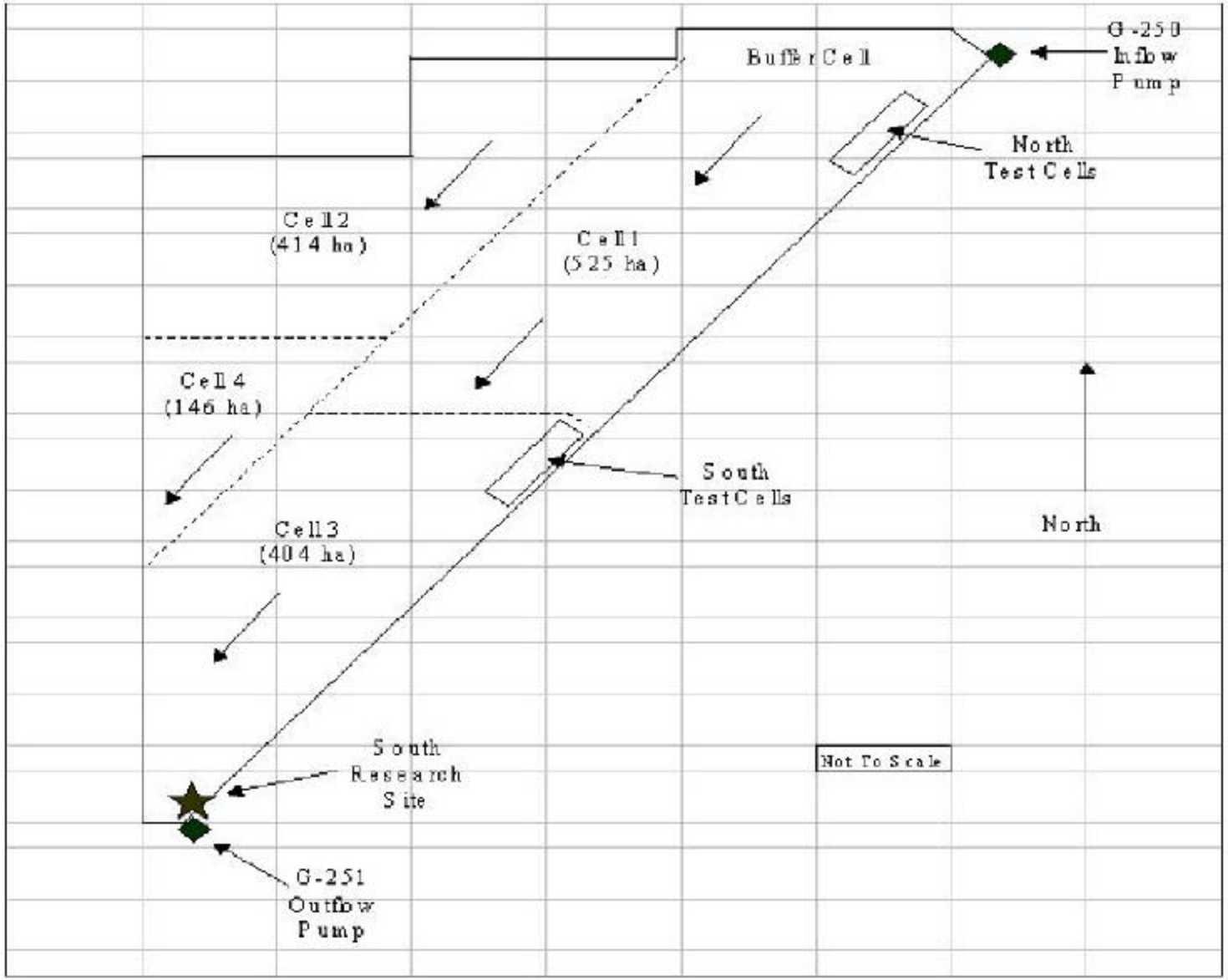


Exhibit 1-1
Site Map

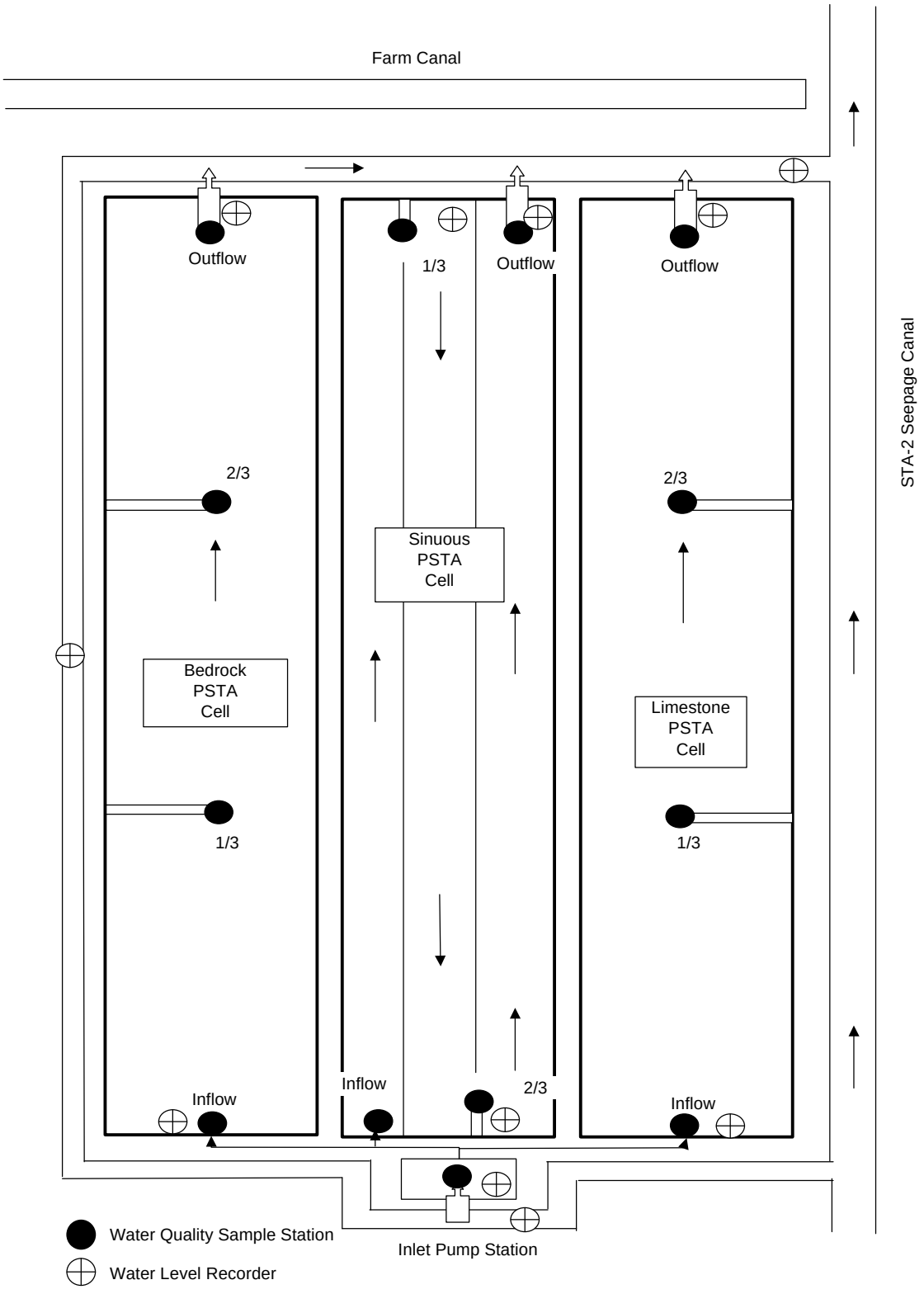


EXHIBIT 1-2
Conceptual Design and Proposed Sampling Stations for Field-Scale PSTA Research Facility

SECTION 2

Site Access and Safety

2.1 Site Access

Phase II project activities will be conducted at three sites: the Supplemental Technologies Area and the South ENR Test Cells within the ENR Project and also at the Field Scale Cells within STA II. The sites are fenced, and access is controlled, as contractors must obtain authorized keys from the District. There is also a security guard and gate at the main entrance to the ENR adjacent to the C-51 canal. Security is maintained 24 hours per day, and to the extent possible, work will be limited to daylight hours. All visitors to the site must be accompanied by a member of the CH2M HILL project team. Exhibit 2-1 will be used as the visitor sign-in sheet.

2.2 Traffic Safety

Due to the number of construction activities currently underway, the Everglades Construction Project (ECP) area is subject to increased traffic and congestion. Therefore, the number of personal vehicles brought to the site should be limited. When possible, personnel should car pool to the ENR site.

The project team will coordinate with Richard Meeker (phone number 561-686-8800 ext. 6942), the ENR project manager, as necessary to keep him informed of planned work activities. Reduce the number of trips made to the site by combining multiple shipments of equipment when possible. When driving in the area, use caution. Roads are generally single lane, with occasional pull-over areas to allow an opposing vehicle to stop outside the roadway and let oncoming traffic pass. Large construction vehicles have difficulty stopping in a short distance and maneuvering along the soft shoulders – plan to use the pull-over areas and yield to the large construction vehicles. Drive courteously and obey the posted speed limits.

2.3 Heavy Equipment

Personnel shall wear orange clothing or vests when working around heavy equipment. It is anticipated that all work involving heavy equipment will be conducted during daylight

hours. A spotter must be provided during all activities that require lifting of equipment, and employees shall not stand or pass under suspended loads.

2.4 Special Restrictions for Work in ENR Test Cells and STA II Field Scale Cells

Generally, the test cells or field scale cells will be drained before construction-related work is conducted within the cells. Monitoring activities will involve work at the cells while there is standing water in them. The majority of the cell monitoring will be conducted from the shore or from the walkways; no cell entry is required nor allowed on a routine basis since such entry would disrupt the field experiments. When study activities require workers to enter the cells and/or carry heavy equipment or samples on walkways, work will be performed using the buddy system. A second person will provide assistance from the shore, if needed. Additional protective clothing such as leather gloves, waders and steel-shank waterproof boots shall be worn by both persons, where entry into the cells is required.

Exhibit 2-1

PSTA Visitor Sign-In Sheet

VISITOR SIGN-IN SHEET				
Date	**Time**	**Name (Print)**	**Name (Signature)**	**Affiliation**

SECTION 3

Operation Control Measures

3.1 Training

Training will be a regular, continuing activity. All employees will receive information and training regarding this Safety Plan. The training course for the Safety Plan will include the applicable portions of the OSHA Occupational Exposures to Hazardous Chemicals in Laboratories Standard (29 CFR 1910.1450) and its appendices. This standard will be made available to employees.

Ongoing training will consist of bi-monthly safety meetings to review established safety procedures, discuss potential problems, and brainstorm safe work solutions. The safety officer and the project manager shall document this ongoing employee training. Exhibit 3-1 provides a form for documenting this training.

3.2 Safe Work Practices

All persons entering and/or working at the project site shall adhere to the following safe work practices.

- All persons working on this project at the field site shall read and be familiar with this safety plan. The safety officer will ensure each field team member is familiar with the plan.
- All visitors will be required to sign in on the sign-in sheet provided as Attachment 2. This sheet will be kept in the project trailer at the supplemental technologies site.
- There will be no smoking, eating, chewing gum, drinking or any activities that involve hand to mouth/face contact in areas where chemicals are stored, handled or used.
- Hands, face and all areas potentially exposed to chemicals shall be thoroughly cleaned prior to smoking, eating or leaving the project site
- Avoid behavior that might confuse, startle, or distract another worker.
- All accidents and/or injuries shall be immediately reported to the safety officer and project manager.

- No matches or lighters will be allowed in the chemicals storage facility or in areas where flammable hazards exist.
- Proper lifting techniques will prevent straining back muscles. Assess the weight of the object to be lifted, use legs when lifting, and get help if necessary. Use a back support brace if advised by a physician.
- Avoid the use of contact lenses at work. If they are to be worn, advise the safety officer so that special precautions can be taken, such as wearing safety goggles.

3.3 Electrical

The following precautions shall be followed to prevent electrical hazards at the work trailer:

- Electrical outlets must have a grounding connection (three-pronged plug) or an approved insulated casing.
- Control panels and circuits must identify outlets so they can be quickly turned off.
- Outlets shall be located so as to minimize the possibility of water or chemicals being accidentally spilled on them.
- Eliminate wiring that is worn or frayed.
- Extension cords should only be used as a temporary source of power.
- Electrical control panels shall not be obstructed.

Exhibit 3-1
PSTA Training Documentation Form

Name & Company	Date
Facilitator:	
Topics Discussed:	

SECTION 4

Procedures and Control Measures for Working with Potentially Harmful Chemicals

4.1 Personal Protective Equipment

The key factor in working safely with potentially harmful chemicals is preventing or minimizing exposure to chemicals. Through the use of engineering controls, administrative controls and personal protective equipment, one can eliminate or greatly reduce the level of exposure to chemicals.

In addition to items for personal wear (i.e. closed toe shoes), the following personal protective equipment will be available for use, if needed, and maintained in clean and serviceable condition at project trailers:

- Face shield (1)
- Goggles (1 pair)
- Heavy rubber gloves (2 pair)
- Leather work gloves (2 pair)

These are the minimum requirements and will not protect workers sufficiently in all situations. Additional personal protective equipment may be required to provide adequate protection against contact with potentially harmful chemicals. Each person working at the project site is responsible for knowing the location and proper use of the available personal protective equipment and safety equipment.

4.2 Eye Protection

Eye protection is required for all personnel and visitors who use chemicals and where the potential for being splashed exists. The types of eye and face protection are:

- **Safety Glasses:** Safety glasses with side shields used at the project trailer must meet the standards set by the American National Standards Institute (ANSI).
- **Goggles:** Goggles should be worn when there is a danger of splashing chemicals or flying particles. Chemical splash goggles, meeting ANSI requirements, must be worn when personnel are working with concentrated acids, bases, and organic chemicals.

- **Face Shields:** These are used when handling concentrated acids or bases. They provide protection for the face and throat from splashes caused by physical impact or uncontrolled chemical reaction of solutions. Safety goggles shall be worn with the face shields.

4.3 Gloves

Gloves shall be selected based on the material being handled, the particular hazard involved, and their suitability for the operation being conducted. Before each use, rubber gloves shall be inspected for discoloration, punctures, and tears. Before removal, gloves shall be rinsed. Gloves shall be replaced whenever there is physical damage to the glove or if there is evidence that the glove is losing effectiveness.

- **Leather-palmed heavy cotton gloves** shall be used for general work activities at the site that involve handling abrasive or sharp objects or when picking up broken glassware.
- **Rubber gloves** shall be used for handling acids, aqueous liquids and solids.
- **Vinyl rubber gloves** shall be used for handling organic liquids with the possibility of solvent contact.

4.4 Foot Protection

Steel-toed boots or shoes must be worn during any construction operation or when moving heavy equipment, containers or drums. Closed toe shoes, as a minimum, will be mandatory for all persons working at the PSTA sites.

4.5 Contaminated Personal Protective Equipment

Articles of personal protective equipment that are contaminated represent a potential exposure for employees.

- Disposable gloves should be removed and disposed of as soon as practical to minimize personnel exposure.
- Gloves that can be reused should be decontaminated as soon as practical.

4.6 List of Chemicals

A list of chemicals that may be used and stored at the project trailer is provided for both the ENR and STA II sites in Exhibits 4-1 and 4-2.

EXHIBIT 4-1
Potential Chemicals Used/Stored at the ENR PSTA Trailer

Chemical	Quantity	Owner	Location	MSDS available	Container properly labeled
10% Hydrochloric acid	10 L	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Sulfuric acid	500 mL	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Nitric acid	500 mL	CH2M HILL	PSTA TRAILER ACID CABINET	Yes	Yes
Formaldehyde	500 mL	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Feldspar	4-50lb bags	CH2M HILL	PSTA site	Yes	Yes
Lithium chloride	50lb drum	CH2M HILL	PSTA Trailer	Yes	Yes
Bromide	500 mL	CH2M HILL	PSTA Trailer	Yes	Yes

EXHIBIT 4-2
Potential Chemicals Used/Stored at the STA 2 PSTA Trailer

Chemical	Quantity	Owner	Location	MSDS available	Container properly labeled
10% Hydrochloric acid	2-500 mL	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Sulfuric acid	500 mL	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Nitric acid	500 mL	CH2M HILL	PSTA TRAILER ACID CABINET	Yes	Yes
Formaldehyde	500 mL	CH2M HILL	PSTA Trailer Acid Cabinet	Yes	Yes
Feldspar	4-50lb bags	CH2M HILL	PSTA site	Yes	Yes
Lithium chloride	50lb drum	CH2M HILL	PSTA Trailer	Yes	Yes
Bromide	500 mL	CH2M HILL	PSTA Trailer	Yes	Yes

4.7 Material Safety Data Sheets

A notebook will be maintained in the project trailers that contains an MSDS for each chemical that is to be transported to or stored onsite.

4.8 Labels and Other Warnings

An original label shall be considered adequate if it contains the following information:

- Identity of the hazardous chemical components
- Appropriate hazard warnings
- Name and address of manufacturer
- Personal protective equipment required

If inadequate, original labels may be replaced using the Hazardous Materials Identification System (HMIS). Examples of the HMIS may be found in the District's Hazardous Waste Safety Program. Original labels shall not be covered, defaced or destroyed. This system may also be used to label previously unlabeled secondary containers. All containers used for storing potentially hazardous chemicals shall be labeled.

SECTION 5

Emergency Procedures

Emergency telephone numbers shall be posted at the project trailers. At a minimum the posted information will include the numbers provided in Exhibit 5-1. Staff working at the ENR sites will carry a cellular phone for site safety and project coordination purposes.

EXHIBIT 5-1
Emergency Contact Telephone Numbers

Contact	Emergency Telephone Number
Project Manager Steve Gong	954-426-6112 ext. 231
Field activities coordinator Ellen Patterson	954-426-6112 ext. 233
Safety Officer Fran Bennett	954-426-6112 ext. 216
District Operations	561-682-6116
District Security	561-682-6449
ECP Front Gate – Guard	561-753-2457
Local Fire Department	911
Local Police Department	911
Local Medical Emergency Team	911
Palms West Hospital	561-798-6010
Glades General Hospital	561-996-6571
CHEMTREC (poison information/first aid)	800-424-9300

5.1 Fire Extinguishers

A fire extinguisher shall be located at the project trailers.

5.2 Eye Wash

An emergency eye wash kit will be maintained at the trailers where chemicals will be used and stored.

5.3 First Aid/Medical Treatment

The project trailers will have a first aid kit, which will be approved and maintained by the safety officer. The first aid kit will contain standard supplies for treatment of common injuries. The safety officer will be trained in administering first aid. Quick response to assist the victim involved in an accident or spill can significantly minimize injury.

In the event an employee is splashed in the eyes with chemicals, immediately flush the eyes with water for at least 15 minutes using the eye wash station. If skin contact is extensive, flush with potable water for 15 minutes while removing contaminated clothing. Immediately seek medical attention. Maps with the routes to the nearest hospital emergency room are provided in Exhibit 5-2.

All injuries and illnesses must be reported to the safety officer and project manager. Minor injuries requiring only first aid will be treated onsite and logged by the site safety officer.

The local hospital for the ENR is Palms West Hospital located at 13001 Southern Boulevard and for STA 2 the local hospital is Glades General Hospital located at 1201 S. Main in Belle Glade. Minor injuries requiring professional medical attention should be handled by driving the injured person to the local hospital. For serious injuries and life threatening conditions, the local emergency medical team should be contacted via 911 and brought to the site to assist and transport the victim.

5.4 Chemical Spills

Appropriate absorbent material/pads will be stored in the project trailers to clean-up any chemical spills at the project site. All absorbent material will be properly disposed of.

5.5 Accident/Spill Reporting

Immediately following an accident or spill at the project site, the site safety coordinator will report the incident to the CH2MHILL project manager who will notify the District project manager as soon as possible and no later than 24-hours following the incident.

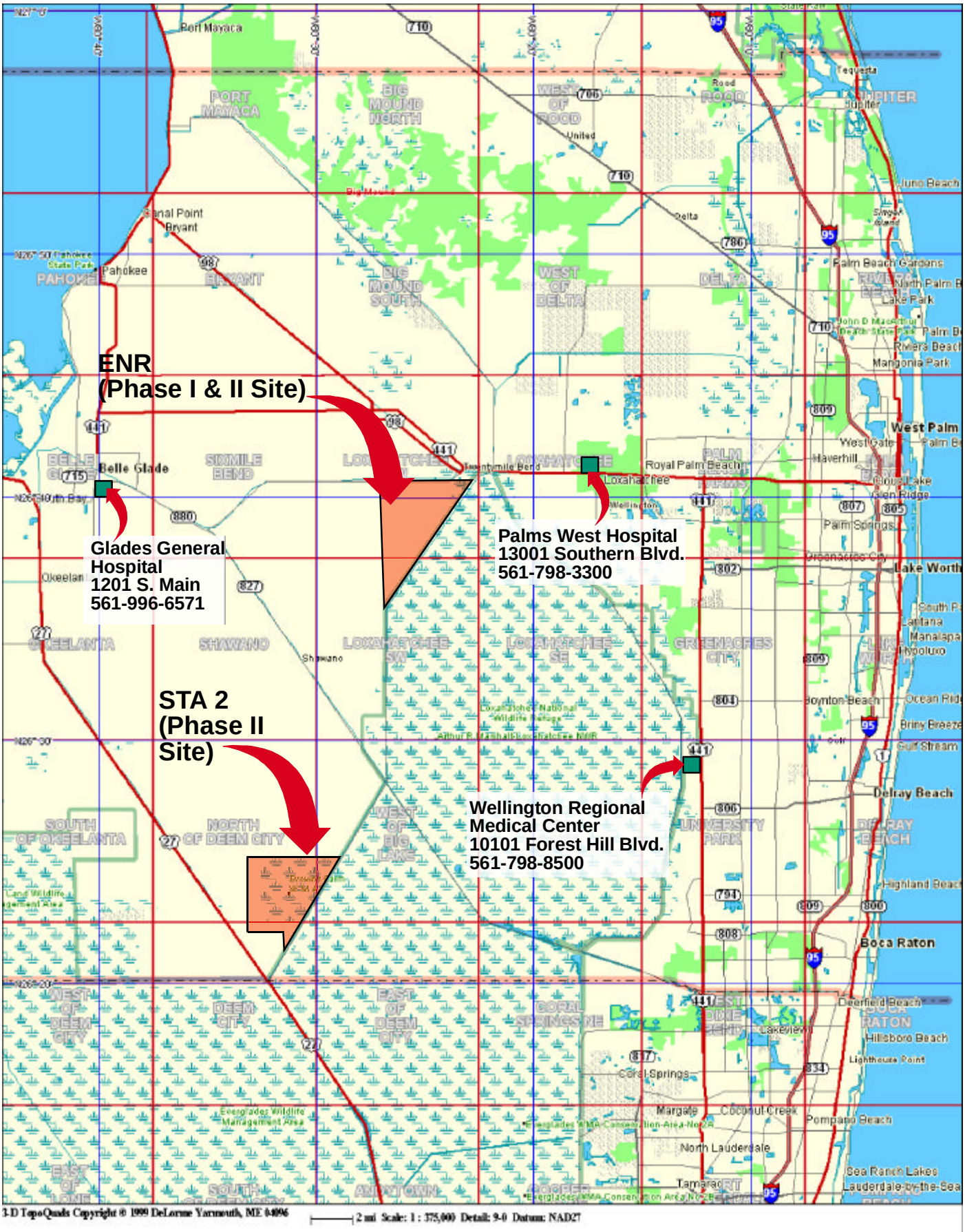


Exhibit 5-2
Map to Nearest Medical Facility from ENR and STA 2

Appendix A
Supplemental Field Safety Instructions

CH2MHILL

FIELD SAFETY INSTRUCTIONS

These Field Safety Instructions (FSI) will be kept onsite and will be made available for review during field activities. The FSI will be reviewed and updated as project activities or conditions change or when supplemental information becomes available that would make the FSI inadequate or ineffective. The FSI adopts, by reference, the Standards of Practice (SOPs) contained in the CH2M HILL *Corporate Health and Safety Program, Program and Training Manual.* The Designated Safety Coordinator is to be familiar with these SOPs and the content of these instructions. In addition, these FSI may adopt procedures from CH2M HILL, contractor or subcontractor project work plans.

PROJECT NAME:	**Periphyton Based Stormwater Treatment (PSTA) Project**
PROJECT NUMBER.:	**148010**
PROJECT MANAGER:	**Steve Gong/DFB**
CH2M HILL OFFICE:	**Deerfield Beach, Florida**
CLIENT:	**South Florida Water Management District**
DATES OF SITE WORK:	**December 1998 to August 2001**
SITE ADDRESS:	**Everglades Nutrient Removal (ENR) Project and Storm Water Treatment Area (STA) 2**
PROJECT DESCRIPTION:	**Research project and pilot testing of the PSTA concept to meet the Everglades Forever Act of 1994 criteria for alternative supplemental technology evaluation.**

1.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

1.1 Client

Client: **South Florida Water Management District**

Contact Name: **Lori Wenkert**

Telephone: **561-682-6661**

1.2 CH2M HILL

Description of specific tasks to be performed by CH2M HILL:
Conduct water quality, sediment and periphyton monitoring as outlined in the PSTA Research Plan.

Project Manager: **Steve Gong/DFB**

Health and Safety Manager (HSM): **Angelo Liberatore/ATL**

Designated Safety Coordinator (DSC): **Fran Bennett/DFB**

The DSC is responsible for verifying that the project is conducted in a safe manner including the following specific obligations:

- verify these FSI are current and amended when project activities or conditions change
- verify CH2M HILL site personnel and subcontractor personnel read these FSI and sign Attachment 1 "Employee Signoff Sheet" prior to commencing field activities
- verify CH2M HILL site personnel and subcontractor personnel have completed the required training and medical surveillance as identified in section 2 and document on Attachment 1 "Employee Signoff Sheet"
- verify compliance with the requirements of these FSI and applicable subcontractor health and safety plan(s)
- verify that Attachment 2 "Project Hazard Communication Form" is completed and that training is provided on the hazards associated with the listed chemicals and the control measures to be used to prevent exposure to CH2M HILL and subcontractor personnel.
- act as the "Emergency Response Coordinator" during a facility or medical emergency
- post OSHA job-site poster; the poster is required at sites where project field offices, trailers, or equipment-storage boxes are established; posters can be obtained by calling 800/548-4776 or 800/999-9111
- verify that periodic safety meetings are conducted and documented in the project file
- verify that project H&S forms/permits, found in Attachment 4, are being used as outlined in section 2
- verify that project activity assessment checklists, found in Attachment 5, are being used as outlined in section 2

1.3 Subcontractors

The following subcontractors are covered by these FSI as specified in the project documents (e.g., contract). However, these FSI do not address hazards associated with tasks and equipment that the subcontractor has expertise in (e.g., operation of drill rig, excavation activities). Subcontractors are responsible for health and safety plans specific to their work and are to submit these plans to CH2M HILL for review and attachment to these FSI before the start of field work. Subcontractors must comply with the requirements of these FSI and other established health and safety plan(s). CH2M HILL must monitor and enforce compliance with the established plan(s).

Subcontractor: **Brown and Caldwell**

Contact Name: **Joel Chavez**

Telephone: **561-684-3456**

Competent Person(s): **Roger Copp**

Telephone: **813-889-9515**

Description of specific task(s) to be performed by subcontractor:
Assist with field activities as directed by CH2M HILL

Subcontractor: **Bob Knight**

Contact Name: **Bob Knight**

Competent Person(s): **Bob Knight**

Telephone: **904-462-1003**

Description of specific task(s) to be performed by subcontractor:
Senior advisor and principal investigator

General health and safety communication with subcontractors contracted with CH2M HILL and covered by these FSI are to be conducted as follows:

- Subcontractors will be provided a copy of these FSI and are required to read and sign Attachment 1 "Employee Signoff Sheet"
- Notify the subcontractor-designated representative if a violation of these FSI or other established plan(s) is observed. Subcontractors are responsible for determining appropriate hazard controls and mitigating hazards with which they have expertise
- If a hazard condition persists, make clear that consistent violations of these FSI and health and safety plans by a subcontractor may result in termination of the subcontract
- When an apparent imminent danger exists, promptly remove all affected personnel. Notify the project manager, subcontractor and HSM as appropriate
- Verbal communication with a subcontractor concerning hazard abatement should be documented in the project records

1.4 Contractors/Third-Party

These FSI do not cover contractors or other third-parties that are contracted directly to the client or the owner. CH2M HILL is not responsible for directing contractor personnel and is not to assume responsibility for their safety through our actions. When the contractor is in control of the site, request the contractor to conduct a briefing of their health and safety practices to determine how they impact CH2M HILL's activities. A copy of the contractor's health and safety procedures should be maintained onsite for reference.

Contractor/Third-Party:

Contact Name:

Telephone:

Description of specific task(s) to be performed by contractor:

General health and safety communications with contractors and other third parties *not* contracted with CH2M HILL are listed below.

- When a contractor is in control of the site, CH2M HILL's obligation is limited to informing the contractor of a hazardous condition. CH2M HILL employees are not to direct the details of the contractor's work or to advise on health and safety (e.g., how the contractor corrects unsafe conditions)

- If an observed hazard poses a risk to CH2M HILL personnel, notify the party controlling the work activity as soon as possible. Notify the project manager; the project manager will notify the client. Document oral notification in project records (i.e., the field logbook)

- If a hazardous condition endangering a CH2M HILL employee persists, remove the employee and inform the contractor and the project manager (the project manager will contact the client) that CH2M HILL cannot execute the assigned work until the hazard is mitigated

- When an apparent imminent danger exists, orally warn the person(s) in danger and orally notify the contractor promptly, CH2M HILL does not have stop-work authority in this contractual relationship. When an imminent danger involves a CH2M HILL employee, remove the employee and immediately suspend CH2M HILL work associated with the danger until the hazard has been mitigated. Inform the project manager and the contractor promptly

- The DSC or the project manager must notify the client and HSM when (1) the contractor fails to remedy an unsafe condition affecting CH2M HILL personnel, (2) the contractor does not remedy the hazardous condition within a reasonable period of time, or (3) the contractor repeatedly creates the hazardous condition

2.0 HAZARD EVALUATION AND CONTROL MEASURES

The control measures used to reduce or eliminate exposure to the following hazards are presented according to the activity being performed. Personnel must comply with the requirements of the activities in which they are performing or exposed. Personnel who do not understand any of the requirements should contact the DSC for clarification.

2.1 Physical Hazards

The following physical hazards may exist on this project.

2.1.1 General Activities

The following guidelines are provided regarding safe operating protocols. For additional information, refer to Appendix A.

Personal Protective Equipment

ANSI approved eye and face protection must be worn when exposed to hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation. **Personnel handling acids and caustics must wear chemical splash goggles and rubber gloves. A face shield shall be worn when a chemical splash hazard is present. A eye wash must be located in the immediate vicinity of acid and caustic handling areas.**

ANSI approved hard-hats must be worn when there is potential of head injury from impact, falling or flying objects, or electrical shock and burns.

Appropriate protective footwear must be worn when working in areas where there is a danger of foot injuries due to falling or rolling objects, objects piercing the sole, or when the feet are exposed to electrical hazards.

Appropriate hand protection must be worn when exposed to hazards such as those from skin absorption of harmful substances, severe cuts or lacerations, severe abrasions, punctures, chemical burns, thermal burns and harmful temperature extremes.

Hearing protection must be worn when working around heavy equipment or other noisy machinery. The following general rule of thumb should be used to determine if hearing protection is required in a specific area. If you must raise your voice to be heard while communicating with persons near you, hearing protection is required.

Inadequate Illumination

Site work will be performed during daylight hours whenever possible. Work conducted during hours of darkness will require enough illumination intensity "to read a newspaper without difficulty."

Housekeeping

- Good housekeeping must be maintained at all times in all project work areas.
- Common paths of travel should be established and kept free from the accumulation of materials.
- Keep access to aisles, exits, ladders, stairways, scaffold and emergency equipment free from obstructions.
- Specific areas should be designated for the proper storage of materials.
- Tools, equipment, material and supplies shall be stored in an orderly manner.
- As work proceeds, scrap lumber and other unessential items must be neatly stored or removed from the work area.
- Containers should be provided for collection trash and other debris and shall be removed at regular intervals.
- Solvent waste and oily rags must be kept in a fire resistant, covered container until removed from the project site.
- Flammable/combustible liquids must be kept in approved containers and must be stored in an approved storage area.
- All spills shall be quickly cleaned up. Oil and grease shall be cleaned from walking and working surfaces.

Fire Extinguishers

Fire extinguishers shall be provided so that the travel distance from any work area to the nearest extinguisher is less than 100 feet. When 5 gallons or more of a flammable or combustible liquid is being used, an extinguisher must be within 50 feet. Extinguishers must be maintained in a fully charged and operable condition and be inspected visually every month and undergo an annual maintenance check.

Manual Lifting

Proper lifting techniques must be used when lifting any object. Make sure the path of travel is clear prior to the lift. Having someone assist with the lift or using mechanical lifting aids should be used for heavy or awkward loads. A manual lifting training program is available through the *Basic Training Program.*

Electrical Safety

- All temporary wiring, including extension cords, shall have ground fault circuit interrupters (GFCIs) installed.
- Extension cords must also be equipped with third-wire grounding. Cords passing through work areas must be covered, elevated or protected from damage. Cords should not be routed through doorways unless protected from pinching.
- Electrical power tools and equipment must be effectively grounded or double-insulated UL approved.
- Electrical power tools, equipment and cords are to be inspected for damage before use. If damaged, they must be tagged and removed from service.
- Only qualified personnel are to work on energized electrical circuits and equipment. Only authorized personnel are permitted to enter high-voltage areas.

Traffic Safety

- Exercise caution when exiting traveled way or parking along street – avoid sudden stops, use flashers, etc.
- Park in a manner that will allow for safe exit from vehicle, and where practicable, park vehicle so that it can serve as a barrier.
- All staff working adjacent to traveled way or within work area must wear reflective/high-visibility safety vests.
- Eye protection should be worn to protect from flying debris.
- Remain aware of factors that influence traffic related hazards and required controls – sun glare, rain, wind, flash flooding, limited sight-distance, hills, curves, guardrails, width of shoulder (i.e., breakdown lane), etc.
- Always remain aware of an escape route -- behind an established barrier, parked vehicle, guardrail, etc.
- Always pay attention to moving traffic – never assume drivers are looking out for you
- Work as far from traveled way as possible to avoid creating confusion for drivers.
- When workers must face away from traffic, a "buddy system" should be used, where one worker is looking towards traffic.
- When working on highway projects, obtain a copy of the contractor's traffic control plan.
- Work area should be protected by a physical barrier – such as a K-rail or Jersey barrier.
- Review traffic control devices to ensure that they are adequate to protect your work area. Traffic control devices should: 1) convey a clear meaning, 2) command respect of road users, and 3) give adequate time for proper traffic response. The adequacy of these devices are dependent on limited sight distance, proximity to ramps or intersections, restrictive width, duration of job, and traffic volume, speed, and proximity.
- Either a barrier or shadow vehicle should be positioned a considerable distance ahead of the work area. The vehicle should be equipped with a flashing arrow sign and truck-mounted crash cushion (TMCC). All vehicles within 40 feet of traffic should have an orange flashing hazard light atop the vehicle.
- Except on highways, flaggers should be used when 1) two-way traffic is reduced to using one common lane, 2) driver visibility is impaired or limited, 3) project vehicles enter or exit traffic in an unexpected manner, or 4) the use of a flagger enhances established traffic warning systems.
- Lookouts should be used when physical barriers are not available or practical. The lookout continually watches approaching traffic for signs of erratic driver behavior and warns workers. Vehicles should be parked at least 40 feet away from the work zone and traffic. Minimize the amount of time that you will have your back to oncoming traffic.

Wetlands Cell Work

- Test cells will be drained before conducting work within the cells
- Wetlands cell work will be performed using buddy system
- Personnel shall wear leather gloves and (if needed for water) waders.

Ladders

- Ladders must be inspected by a competent person for visible defects prior to each days use, defective ladders must be tagged and removed from service.
- Personnel must face the ladder when climbing, keeping the belt buckle between side rails. Personnel must use both hands to climb; use rope to raise and lower equipment and materials.
- Use ladders at an angle such that horizontal distances from top support to foot of ladder is one-fourth of the working length of the ladder. Ladders must extend at least 3 feet above landing surface.
- Ladders which may be displaced by work activities or traffic must be secured or barricaded.
- Stepladders are to be used in the fully opened and locked position. Personnel are not to stand on the top two steps of a stepladder; nor sit on top or straddle a stepladder.

Heavy Equipment/Motor vehicles

- Never approach operating equipment from the rear. Always make positive contact with the operator, and confirm that the operator has stopped the motion of the equipment.
- Never approach the side of operating equipment; remain outside of the swing and turning radius.
- Maintain distance from pinch points of operating equipment.
- Because heavy equipment may not be equipped with properly functioning reverse signal alarms, never turn your back on any operating equipment.
- Never climb onto operating equipment or operate contractor/subcontractor equipment.
- Never ride contractor/subcontractor equipment unless it is designed to accommodate passengers; equipped with firmly attached passenger seat.
- Never work or walk under a suspended load.
- Never use equipment as a personnel lift; do not ride excavator buckets or crane hooks.
- Always stay alert and maintain a safe distance from operating equipment, especially equipment on cross slopes and unstable terrain.

2.2 Health Hazards

The following health hazards may exist on this project. Personnel who experience symptoms of contaminant exposure must terminate their activity and contact the DSC.

2.3 Chemical Hazards

CH2M HILL's written *Hazard Communication Program* is available from area or regional offices and from the Corporate Human Resources Department in Denver. All CH2M HILL site employees and subcontractors potentially exposed to hazardous chemicals must receive project-specific training.

The DSC will verify that Attachment 2 "Project Hazard Communication Form" is completed and that personnel exposed to hazardous chemicals are provided with appropriate hazard communication training. Refer to SOP HS-05 *Hazard Communication* for more detailed information.

The following approximate chemical volumes will be used during the project at each site:

- **Hydrochloric Acid (10 L)**
- **Sulfuric Acid (500 mL)**
- **Feldspar (4-50lb bags)**
- **Lithium Chloride (50lb drum)**

- **Bromide (500 ml)**
- **Nitric Acid (500 mL)**
- **Formaldehyde (500 mL)**

Shipping and Transportation of Chemical Products

CH2M HILL personnel who ship or transport materials that are considered hazardous materials by the US Department of Transportation (DOT) must receive CH2M HILL training in shipping dangerous goods. All hazardous materials that are shipped (e.g., via Federal Express) or are transported by road must be properly identified, labeled, packed, and documented by trained staff. Contact the HSM or the Equipment Coordinator for additional information.

2.4 Biological Hazards

The following biological hazards may exist on this project. The control measures presented in this table should be used to reduce or eliminate exposure. Refer to SOP HS-03 *Biological Hazards* for more detailed information.

Hazard	Control Measures
Ticks	Located in low lying shrubs and tall grass. Cover all body parts to wrist and ankles; use repellent on exposed skin surfaces. Perform periodic body checks.
Bees and other stinging insects	Watch for and avoid nests. Keep exposed skin to a minimum. If you have had allergic reactions in the past, inform the DSC and/or your buddy and carry a anti-reaction kit. If a stinger is present, remove it carefully with tweezers. Wash and disinfect the wound, cover it, and apply ice. Watch for allergic reaction; seek medical attention if a reaction develops.
Snakes	Look for snakes in areas with tall vegetation that are rarely disturbed and inside of items around the site that are not used often (buckets, pieces of pipe, etc.). There are many types of snakes at the site some are dangerous and others are not. To be safe do not attempt to pick-up or handle any snake.
Poison ivy, poison oak and poison sumac	Become familiar with the identity of these plants. Wear protective clothing that covers exposed skin.. Avoid contact with plants and the outside of protective clothing. If contact is made, wash the area with soap and water immediately. If the reaction is severe or worsens, seek medical attention.
Wastewater and sewage	Avoid contact to exposed portions of the body and use good personal hygiene practices.
Bloodborne pathogens	Training is required before a task involving potential exposure is performed. Exposure controls and personal protective equipment (PPE) are required as specified in CH2M HILL SOP HS-36, *Bloodborne Pathogens*. Hepatitis B vaccination must be offered before the person participates in a task where exposure is a possibility.

3.0 EMERGENCY RESPONSE

3.1 Emergency Response Coordinator

The DSC will act as the "Emergency Response Coordinator" and has the following responsibilities:

- Complete Attachment 3 "Emergency Information Form" with project-specific information and post next to project telephones
- Complete and post route to hospital and site map identifying location of evacuation routes, assembly areas, and emergency equipment and supplies.
- Coordinate emergency response with the facility and local emergency response providers as appropriate.
- Designate an emergency vehicle; place hospital directions inside; keep keys in ignition during field activities.
- Communicate emergency procedures with all CH2M HILL site employees and subcontractors.

3.2 Emergency Procedures

Site emergency alarms/signals:

NA

Site evacuation routes:

NA

Site evacuation assembly areas:

NA

Site evacuation procedure:

- Personnel will leave the work area, via the excavation routes, and gather at the assembly areas upon hearing the emergency signal for evacuation.
- The DSC will account for all personnel at the assembly area.
- The DSC will communicate and coordinate emergency actions with the local emergency providers and the client.
- The DSC will write up the incident as soon as possible after it occurs and will submit a report to the corporate director of health and safety.

3.3 Emergency Equipment and Supplies

The DSC should verify that these supplies are available and in proper working order and should mark the locations of emergency equipment on the site map.

Emergency Equipment and Supplies	Location
20 lb (or two 10-lb) fire extinguisher (A, B, and C classes)	ENR and Field-Scale Project trailers
First aid kit	ENR and Field-Scale Project trailers
Eye wash	ENR and Field-Scale Project trailers
Potable water	ENR and Field-Scale Project trailers /field vehicles
Bloodborne-pathogen kit	ENR and Field-Scale Project trailers
Cellular Telephone	ENR and Field-Scale Project trailers /field

	vehicles

3.4 Emergency Medical Treatment

The following emergency medical treatment procedures should be implemented in response to serious injuries/illnesses:

- Notify appropriate emergency responders listed in Attachment 3 "Emergency Information Form" (e.g., 911).
- The DSC will assume charge during a medical emergency until the ambulance arrives or until the injured person is admitted to the emergency room.
- Prevent further injury and initiate first aid and CPR where feasible.
- Make certain that the injured person is accompanied to the emergency room.
- Notify the field team leader, project manager, HSM and corporate director of health and safety of the injury.
- Complete CH2M HILL's "Accident Reporting Form" and submit the form to the corporate director of health and safety and the corporate human resources department (COR) within 24 hours. Refer to SOP HS-14 *Injury and Illness Reporting* for more detailed information.

Suspected chemical overexposure incidents

- During a time of no emergency, contact CH2M HILL's Medical Consultant for advice and guidance. Refer to Attachment 3 "Emergency Information Form" for the phone number.
- State that you are calling about a CH2M HILL matter, and give your name, your telephone number, the name of the injured person, the extent of the injury or exposure, and the name and location of the medical facility where the injured person was taken.

4.0 APPROVAL

These FSI have been written for use by CH2M HILL and their subcontractors only. CH2M HILL claims no responsibility for its use by others unless that use has been specified and defined in project or contract documents. These FSI are written for the specific site conditions, purposes, dates, and personnel specified and must be amended if those conditions change.

Written by: **Ellen Patterson** **Date:** **May 2000**

Approved by: **Angelo Liberatore/ATL** **Date:**

4.1 AMENDMENTS

Changes made by: **Ellen Patterson** **Date:** **May 11, 2000**

Changes to Instructions: **Updated instructions to include the Phase 2 project site**

Amendment approved by: **Angelo Liberatore/ATL** **Date:**

5.0 DISTRIBUTION

An approved copy of these FSI shall be provided to the following personnel:

Name	Office	Responsibility	Copies
Angelo Liberatore	ATL	Health and Safety Manager/Approver	1
Steve Gong	DFB	Project Manager	1
Fran Bennett	DFB	Designated Safety Coordinator	5
Ellen Patterson	DFB	Field Activities Coordinator	1

6.0 ATTACHMENTS

Attachment 1: Employee Signoff Sheet - Field Safety Instructions
Attachment 2: Project Hazard Communication Form
Attachment 3: Emergency Information Form
Attachment 4: Project H&S Forms/Permits
Attachment 5: Project Activity Assessment Checklists

CH2MHILL

EMPLOYEE SIGNOFF SHEET - FIELD SAFETY INSTRUCTIONS

The CH2M HILL project employees and subcontractors listed below have been provided with a copy of this FSI, have read and understood it, and agree to abide by its provisions.

EMPLOYEE NAME (Please print)	**EMPLOYEE SIGNATURE**	**COMPANY**	**DATE**	***DSC USE ONLY TRNG/MEDICAL VERIFIED***

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PROJECT HAZARD COMMUNICATION FORM

This form shall be completed prior to performing activities that expose personnel to hazardous chemicals. The form will serve the following purposes: 1) act as the project chemical inventory list, 2) verify that a material safety data sheet (MSDS) is available for each chemical , 3) verify that all hazardous chemical containers are properly labeled, 4) identify the location where MSDS's can be obtained, and 5) act as a project-specific hazard communication training tool. The Designated Safety Coordinator (DSC) shall request an inventory list and appropriate MSDS's from the client, contractors and subcontractors for chemicals to which CH2M HILL and subcontractor personnel potentially are exposed. Upon completion of this form the DSC shall verify that training is provided on the hazards associated with these chemicals and the control measures to be used to prevent exposure to CH2M HILL and subcontractor personnel. Labeling and MSDS systems will also be explained.

Project Name: PSTA **Project Number: 148010**

The chemical products list below may be present or used on this project at the ENR PSTA trailer.

Chemical	Quantity	Owner	Location	MSDS available	Container properly labeled
Hydrochloric acid	**10 L**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Sulfuric acid	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Feldspar	**4-50lb bags**	**CH2M HILL**	**PSTA site**	**Yes**	**Yes**
Lithium chloride	**50lb drum**	**CH2M HILL**	**PSTA Trailer**	**Yes**	**Yes**
Bromide	**500 mL**	**CH2M HILL**	**PSTA Trailer**	**Yes**	**Yes**
Nitric Acid	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Formaldehyde	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**

MSDS's for chemical products listed above will be maintained at: ENR PSTA Trailer

The chemical products list below may be present or used on this project at the Field-Scale site.

Chemical	Quantity	Owner	Location	MSDS available	Container properly labeled
Hydrochloric acid	**2-500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Sulfuric acid	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Feldspar	**4-50lb bags**	**CH2M HILL**	**PSTA site**	**Yes**	**Yes**
Lithium chloride	**50lb drum**	**CH2M HILL**	**PSTA Trailer**	**Yes**	**Yes**
Bromide	**500 mL**	**CH2M HILL**	**PSTA Trailer**	**Yes**	**Yes**
Nitric Acid	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**
Formaldehyde	**500 mL**	**CH2M HILL**	**PSTA Trailer Acid Cabinet**	**Yes**	**Yes**

MSDS's for chemical products listed above will be maintained at: Field-Scale PSTA Trailer

CH2M HILL's written *Hazard Communication Program* is available from area or regional offices and from the Corporate Human Resources Department in Denver. Refer to SOP HS-05 *Hazard Communication* for more detailed information.

CH2MHILL

EMPLOYEE SIGNOFF SHEET - PROJECT HAZARD COMMUNICATION

The CH2M HILL and subcontractors personnel listed below have been provided with project-specific hazard communication training regarding the hazardous chemicals list on this form.

EMPLOYEE NAME (Please print)	**EMPLOYEE SIGNATURE**	**DATE**

CH2MHILL

EMERGENCY INFORMATION FORM

PROJECT CONTACTS	CH2M HILL CONTACTS
Medical Emergency **Phone** Site Medical Responders: Site Medical Facility: Offsite Medical Facility: Palms West Hospital (561-798-6010) or Wellington Hospital	**CH2M HILL Medical Consultant** *(notify if chemical exposure)* Peter P. Greaney, M.D. WorkCare, Inc. 333 S. Anita Drive Orange, CA 92868 (800) 455-6155 This is a 24-hour coverage number. All after hour (6a.m.-6p.m. Pacific are regular working hours) calls will be answered in 20 minutes.
Fire Emergency Site Fire Responders: 911 Local Fire Department: 911	**Local Occupational Physician** *(notify if medical treatment or chemical exposure)* Contact: Phone:
Spill Emergency Site HazMat Responders: Local HazMat Team:	**Corporate Director Health and Safety** *(notify for all injuries/illnesses)* Name: Mollie Netherland/SEA Phone: 206/453-5000
Security ECP Site Security: (561) 753-2457 Local Police: 911	**Radiation Health Manager (RHM) (Acting)** *(notify if radiation exposure)* Name: Dave McCormack/SEA Phone: 206/453-5000
Designated Safety Coordinator Name: Fran Bennett Phone: (954) 426-6112 Ext: 216	**Regional Human Resources Manager** *(notify for all injuries/illnesses)* Name: Mary Jo Jordan/GNV Phone: 352/335-5877
Health and Safety Manager Name: Angelo Liberatore/ATL Phone:770/604-9182 ext. 592	**Corporate Human Resources Department** *(notify for all injuries/illnesses)* Name: Julie Zimmerman/COR Phone: 303/771-0900
Worker's Compensation and Auto Claims CH2M HILL Tonda Cannavino / TPA Phone:813-874-6522 Ext: 4204 Ingrid Wills /Cor Phone: 303-771-0952 Ext: 2757 **Sterling Administration Services** Bob Mazur	**Federal Express Dangerous Goods Shipping** Phone: 800/238-5355 **CH2M HILL Emergency Number for Shipping Dangerous Goods** Phone: 800/255-3924 **South Florida Water Management District Contacts**

Phone: 800/420-8926 After hours 800/497-4566 Report fatalities AND report vehicular accidents involving pedestrians, motorcycles, or more than two cars. Have emergency medical services for occupational injuries billed to Sterling Administration Services.	**Project Manager:** Lori Wenkert Phone: 561-682-6661 Greg Coffelt Phone: 561-686-8800 Ext: 6871 Front Gate Guard House Phone: 561-753-2457

APPENDIX C

Standard Operating Procedures

Standard Operating Procedure Manual

The following standard operating procedures (SOPs) were followed for fieldwork at the Porta-PSTA mesocosms and ENR South Test Cells from February 1999 to March 2000.

Standard Operating Procedure **Page**

Porta-PSTA Inflow/Outflow Calibration and System Flushing

Equipment Required

500 mL graduated cylinders, stopwatch

Monday Calibrations

1. Record start time and staff gauge reading in spaces provided on *Inflow Calibration and Outflow Log* fieldsheet for the Porta-PSTA that is being calibrated.
2. Using a graduated cylinder, collect outflow of the tank for 30 seconds. Double this value to obtain flow in milliliter per minute (mL/min). Record value on fieldsheet.
3. Repeat at tank inflow. Record inflow value in mL/min in appropriate space provided on fieldsheet.
4. Open inflow valve to flush line. Wearing latex glove, manually remove any excess algal growth from spigot opening. Reduce flow and calibrate in same manner with graduated cylinder and stopwatch to prescribed flow rate. Final inflows may vary by +/-20% from prescribed flow rate. Record time at which final inflow was calibrated and recorded.
5. Repeat steps 1–4 for all tanks.
6. Final outflow readings are taken a minimum of 1 hour after final inflow calibrations are made. Final outflow readings are preferentially taken the longest feasible time in the day after final inflow calibrations are made. Record time at which final outflow was recorded.

Thursday Calibrations and System Flushing

1. Follow steps 1–3 as for Monday Calibrations. Perform outflow recordings and initial inflow recordings on all Porta-PSTAs without performing final inflow flushing and calibration.
2. After completing initial outflow/inflow readings, flush the main line along fence that carries water in from the canal. Open the valve to allow water to flow to slough outside fence then immediately close the valve to prevent water flow to the Head Tank. Allow water to flow freely until the water clears. Open valve to Head Tank, then close valve to slough.
3. Open valve under Head Tank to flush accumulated sediments. Allow water to drain until water clears. Close valve. Open valve of pipe leading from Head Tank to Porta-PSTAs. Allow water to run freely until clears. Close valve.
4. Flush the lines (2) that run along the ground at Porta-PSTA inflows. Allow water to run freely until water clears. Close valves.
5. After all system lines have been flushed, begin again with Step 4 as in Monday Calibrations, flushing the Porta-PSTA inflow valve and calibrating to required flow rate. It may be necessary at times to remove valve and clean with a brush.
6. Perform final outflow readings as in Monday Calibrations.

Porta-PSTA Water Quality Sampling

Equipment Required

Appropriate sample bottles 0.45 µm filters, sulfuric acid, de-ionized water

1. Complete inflow / outflow calibration for all tanks to be sampled that day, minimize contact with inflow and outflow pipes before sampling to avoid dislodging particles.
2. Rinse outflow tube with deionized (DI) water (Zephyrhills brand) to dislodge any loose particles.
3. Sampling schedule is as follows:

	Weekly Event	Monthly Event	Quarterly Event
Inflow	-	TP, TDP	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
Center	-	-	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
Outflow	TP, TDP	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS

4. *Note*: Dissolved Reactive Phosphorus is sampled only at the Head Tank. Field duplicates are taken at a rate of 1 per 10 samples; equipment blanks are taken at a rate of 1 per 20 samples. When taking a field duplicate, note sampling location and time in space provided on the fieldsheet pertaining to that Porta-PSTA. Do not note location on field duplicate bottles. Note time of collection of equipment blank(s) on Head Tank fieldsheet.
5. All sample bottles need to be completed with the following information: initials of sample team, date, and time. Collection time is the same for all bottles filled at a particular sampling station.
6. Take outflow sample first. Do not allow blue outflow tube to come in contact with sample bottle. For those sample bottles that come pre-preserved, take care not to overflow the sample bottle and dilute the preservative. Contrarily, the water sample may be collected in a large bottle containing no preservative and aliquotted into the smaller sample bottles.
7. When applicable, collect samples from center locations next. To collect these samples, place inverted bottle under the water. At mid-depth, slowly turn the bottle upright to allow water to enter, making an effort to cause as little disturbance as possible. At center sample locations, it will be necessary to pour water from one of the bottles containing no preservative into the pre-preserved bottles.

8. Inflow samples should be collected last. Do not allow sample bottles to come in contact with the inflow pipe.

9. Add 1 mL of H_2SO_4 to **TP** sample bottles as a preservative after sample collection. Cap and invert bottles after acid addition to mix thoroughly.

10. Filter **TDP** samples prior to shipping. Filters are one-time use filters. Verify that the Porta-PSTA number of the bottle being filtered from corresponds to the Porta-PSTA number of the bottle being filtered into. After filtering, add 1 mL of H_2SO_4 to preserve. Cap and invert bottles after acid addition to mix thoroughly. Water samples being analyzed for **DRP** do not receive any preservative.

11. Write collection times from sample bottles on corresponding field collection sheets and Chain of Custody sheets prior to shipping.

12. Place bottles in coolers lined with large garbage bags. Keep samples on ice until they are ready to be shipped. Prior to shipping, add two bags of ice to each cooler, knot bags. Tape chain of custody to inside lid of cooler. Tape cooler closed before shipping to laboratory.

Porta-PSTA Periphyton and Sediment Collection Techniques

Equipment Required

Standardized plastic sample ring, scissors, Ziplock bags (1 gallon), decontaminated buckets, plexi-glass cylinder (0.53-foot diameter), pocket staff gauge, small cylinder (0.13-foot diameter) with cap, appropriate sample collection bottles.

1. Determine a sample location using the random number tables that have already been generated. The 'X' value for the tank is the tank width (1 meter) and the 'Y' value for the tank is the tank length (6 meters). The sample location on the random number table is written as an X/Y coordinate. The 0,0 coordinate is at the southwest corner of the tank. Note the sample time on the data sheet.

2. Place the circle of plastic tubing on the water surface at the determined location. Using scissors, cut all aquatic vegetation that falls inside the cylindrical plane created by the plastic circle (plane extends above and below surface of the water). Place vegetation in a plastic Ziplock bag, labeled with Porta-PSTA number, to be sent to the lab for dry weight analysis. Note on data sheet if macrophytes were collected.

3. If a floating periphyton mat falls within the sample location, skim it off the water with your hand and place it in decontaminated plastic bucket marked for that station. Note on data sheet that floating mat was collected.

4. Take large plexi-glass cylinder and push it into the sediment at the same location where vegetation was just cleared. Once water has cleared, determine if a periphyton benthic mat exists. Measure water depth with pocket staff gauge and record on data sheet.

5. If a benthic mat exists, use your hand to skim mat off of the sediment. Try to get the entire mat in one piece if possible, disturbing as little of the sediment as possible. If shells or rocks are on bottom of the collected mat, remove them and place mat in decontaminated bucket. If the mat cannot be collected in one piece, continue collecting all other pieces until the entire mat is collected, again being careful to disturb as little sediment as possible.

6. If no benthic mat is present or appears that it is not possible to collect mat by hand, use the small cylinder cores to collect sample as follows. Place the small cylinder within the large cylinder. Place the red cap on top of the small cylinder and tighten down, making sure to only press the small cylinders approximately 2 centimeters (cm) into the sediment. Slowly lift small cylinder off the bottom while placing your hand over the bottom of the cylinder to keep sample from running out. Place contents of small cylinder into decontaminated bucket. If small cores are used multiple times, place them in a different area within the large cylinder each time (i.e., 12 o'clock, 3 o'clock, 6 o'clock, 9 o'clock). Record on data sheet the number of small cylinder cores collected.

7. After periphyton mat has been collected reach down with inverted sediment jar and scoop sediment into the pre-labeled jar, making sure to only collect the top 10 cm of sediment. After jar is filled, rinse it in the water within the large cylinder to send a "clean" sample jar to the lab.

8. Determine volume of periphyton collected as follows. In lab / trailer, place periphyton into blender. Using a known volume of lab grade DI water, dilute sample up to a measurable volume. Volume of periphyton sample is determined by subtracting amount of water added to the blender from total measurable volume in the blender. After volume of periphyton has been calculated, dilute sample to approximately 1,750 mL to have sufficient sample to fill all six specimen bottles. Re-suspend sample before aliquotting to specimen bottles.

Porta-PSTA Stem Count

Equipment Required

Hand counter, ¼ square meter (m^2) quadrat, PP-PAR, Stems, Cover Fieldsheet

Emergent stems are counted as part of the monthly sampling event in all Porta-PSTAs.

1. Each Porta-PSTA is effectively divided into thirds by two evenly spaced fiberglass cross pieces that support the tank. Stems are counted in each third of the tank created by these divisions. The fieldsheet notes Porta-PSTA thirds as North, Center, and South.
2. Count only live emergent stems. Record on fieldsheet species and number of stems per species for each third of Porta-PSTA tank being examined. Use hand counter/clicker to maintain an accurate count.
3. When stems are too dense to count visually, place the ¼ m^2 quadrat over a representative area. Count stems contained within the quadrat. Record raw number with the notation of "x32" to indicate the quadrat was used for the count. Multiplying the raw number by 32 will give the count equivalent to stems in the one-third-tank division in Porta-PSTAs 1–22. Porta-PSTAs 23 and 24 are 18 m^2 and, therefore, need to be multiplied by a factor of 96 to achieve equivalence of one third of the tank when employing the quadrat.

Porta-PSTA Sediment Trap Collection Technique

Equipment Required

Sediment trap lids, graduated cylinders (10, 100, 250, and 1,000 mL), sediment sample bottles.

1. Place lid on sediment trap while trap is submerged.
2. If several sediment traps are collected at a time, keep those not being immediately processed cold until they can be processed.
3. Wearing gloves, open container (some water may be lost, but little to no sediment will be lost, <1%). Decant off as much water as possible without losing any sediment.
4. Leave a little water in the container to allow washers (weights) to be rinsed off.
5. Remove any extraneous debris, such as snails, rocks, shells, or large pieces of plant material. Rinse any associated sediment from debris back into container.
6. Quantitatively transfer sediment / water slurry into graduated cylinder, scraping any sediment adhering to bottom or sides of container into cylinder.
7. Let settle 10–20 minutes.
8. Make note of total volume in cylinder (water plus sediment) and volume of the settled sediment only.
9. Decant off as much water as possible from cylinder and then let settle another 5-10 minutes (repeat this step if necessary).
10. Record final total volume and sediment volume in cylinder on data sheet.
11. Quantitatively transfer sediment / water slurry into 250 mL jar. If necessary, use squeeze bottle of lab grade DI water to rinse any material adhering to cylinder into specimen jar.
12. Place sample into cooler and keep on ice until all samples are ready to be shipped.
13. Items recorded on data sheet include: date, start time, PSTA number, sediment volume, total volume, and stop time.

Test Cell Water Quality Sampling

Equipment Required

10-foot PVC pole with Velcro tape, appropriate sample bottles, filters, sulfuric acid, DI water

All sample bottles need to be completed with the following information: initials of sample team, date, and time. Collection time is the same for all bottles filled at a particular sampling station.

Head Cell

1. Use pocket staff gauge to obtain a total depth. Water samples are collected at mid-depth. Take a sample bottle containing no preservative and secure it to the PVC sampling pole using the Velcro tape. Plunge the bottle down to mid-depth level and allow it to fill. Fill other sample bottles from the one secured to the pole; plunge as many times as necessary to fill all bottles. Avoid overfilling pre-preserved bottles to prevent loss of preservative.

Test Cells

1. Proceed to outflow of Test Cell. Secure labeled bottle to the PVC sample pole and lower to collect water over the weir 'v-notch'. Fill remaining bottles from one secured to the pole.
2. Sampling schedule is as follows:

	Weekly Event	Monthly Event	Quarterly Event
Inflow	-	TP, TDP	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
1/3 Walkway	-	-	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
2/3 Walkway	-	-	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
Outflow	TP, TDP	TP, TDP, Total N, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS	TP, TDP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS
Head Cell	TP, TDP, DRP	TP, TDP, DRP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS	TP, TDP, DRP, Total N, NH_3, TKN, NO_3/NO_2, TOC, Ca^{++}, Alkalinity, TSS

3. *Note*: Field duplicates are taken at a rate of 1 per 10 samples; equipment blanks are taken at a rate of 1 per 20 samples. When taking a field duplicate, note sampling location and time in space provided on the fieldsheet pertaining to that Test Cell. Do not note location on field duplicate bottles. Note time of collection of equipment blank(s) on Head Cell fieldsheet.

4. To collect water from the walkways, lower inverted bottle (containing no preservative) into water column to mid-depth. Slowly turn bottle upright allowing water to enter bottle, being careful to cause as little disturbance as possible. Fill preserved bottles from water sample collected in bottle containing no preservative.
5. To sample inflow water, remove black plastic inflow pipe from brass orifice. Hold bottle in front of outflow stream until full. The inflow water stream flows at a high rate, therefore bottles containing preservative should be filled from bottles containing no preservative.
6. Add 1 mL of H_2SO_4 to **TP** sample bottles as a preservative after sample collection. Cap and invert bottles after acid addition to mix thoroughly.
7. Filter **TDP** samples prior to shipping. Filters are one-time use filters. Verify that the Test Cell number of the bottle being filtered from corresponds to the Test Cell number of the bottle being filtered into. After filtering, add 1 mL of H_2SO_4 to preserve. Cap and invert bottles after acid addition to mix thoroughly. Water samples being analyzed for **DRP** do not receive any preservative.
8. Write collection times from sample bottles on corresponding field collection sheets and Chain of Custody sheets prior to shipping.
9. Place bottles in coolers lined with large garbage bags. Keep samples on ice until they are ready to be shipped. Prior to shipping, add two bags of ice to each cooler, knot bags. Tape chain of custody to inside lid of cooler. Tape cooler closed before shipping to laboratory for analysis.

Test Cell Water Level Recordings

Equipment Required

Pocket staff gauge, Test Cell Water Elevation Data fieldsheet

Head Cell

1. Read the staff gauge located on north edge of cell, and record value on Test Cell Water Elevation Data fieldsheet along with date and time.

Test Cells

1. Water level recorders are located at ends of east and west walkways of Test Cells in housing boxes. Read the value from tape in housing box (marked in 0.01-foot increments) at both the east and the west recorders; record time and values in appropriate slots of data sheet.
2. At the weir outflow box, read the weir height from the white PVC pole, marked in 0.1-foot increments. Use staff gauge to record in 0.01-foot increments. Record on Test Cell Water Elevation Data fieldsheet.
3. The weir box staff gauge is attached to the wall below the grate inside the weir box. Read the weir box staff gauge (it may be necessary to climb down into weir box to clean algae off gauge), marked in 0.01-foot increments. Record value on fieldsheet.
4. Use the pocket staff gauge to measure the height of the white PVC pole above the metal grate; record value on data sheet.
5. Read the volume of water moving over the v-notch denoted by the rubber stopper within the clear tube above the white PVC pole. The value is read at the bottom of the rubber indicator and must be read directly at eye level for an accurate measurement. Record value on data sheet.
6. Read staff gauge located at west end of Test Cells. Read and record staff gauge in 0.01-foot increments.
7. Repeat Test Cell recording procedures 1–5 at all Test Cells.

Test Cell Periphyton and Sediment Sampling

Equipment Required

Standardized plastic sample ring, scissors, Ziplock bags (1 gallon), decontaminated buckets, plexi-glass cylinder (0.53-foot diameter), pocket staff gauge, small cylinder (0.13-foot diameter) with cap, soil corer auger, appropriate sample collection bottles.

1. Sampling location along walkway is determined using random number tables. The distal end of the walkway is the random unit of '50'; each walkway division is considered a unit of '10.' Periphyton samples are collected on the east side of the walkway, and soil samples are collected on the west side of the walkway. Record start time on the data sheet.

2. Once a sample location has been selected, place the circle of plastic tubing on the surface of the water. Place the circle of plastic tubing on the water surface at the determined location. Using scissors, cut all aquatic vegetation that falls inside the cylindrical plane created by the plastic circle (plane extends above and below surface of the water). Place vegetation in a plastic Ziplock bag, labeled with Test Cell number, to be sent to the lab for dry weight analysis. Note on data sheet if macrophytes were collected.

3. If a floating periphyton mat falls within the sample location, skim it off the water with your hand and place it in decontaminated plastic bucket marked for that station. Note on data sheet that floating mat was collected. A small piece of floating mat needs to be placed in a labeled sample jar for taxonomy identification (no preservative added).

4. Take large plexi-glass cylinder and push it into the sediment at the same location where vegetation was just cleared. Once water has cleared, determine if a periphyton benthic mat exists. Measure water depth with pocket staff gauge and record on data sheet.

5. If a benthic mat exists, use your hand to skim mat off of the sediment. Try to get the entire mat in one piece if possible, disturbing as little of the sediment as possible. If shells or rocks are on bottom of the collected mat, remove them and place mat in decontaminated bucket. If the mat cannot be collected in one piece, continue collecting all other pieces until the entire mat is collected, again being careful to disturb as little sediment as possible.

6. If no benthic mat is present or appears that it is not possible to collect mat by hand, use the small cylinder cores to collect sample as follows. Place the small cylinder within the large cylinder. Place the red cap on top of the small cylinder and tighten down, making sure to only press the small cylinders approximately 2 cm into the sediment. Slowly lift small cylinder off the bottom while placing your hand over the bottom of the cylinder to keep sample from running out. Place contents of small cylinder into decontaminated bucket. If small cores are used multiple times, place them in a different area within the large cylinder each time (i.e., 12 o'clock, 3 o'clock, 6 o'clock, 9 o'clock). Record on data sheet the number of small cylinder cores collected.

7. Determine volume of periphyton collected as follows. In lab / trailer, place periphyton into blender. Using a known volume of lab grade DI water, dilute sample up to a measurable volume. Volume of periphyton sample is determined by subtracting amount

of water added to the blender from total measurable volume in the blender. After volume of periphyton has been calculated, dilute sample to approximately 1,750 mL to have sufficient sample to fill all six specimen bottles. Re-suspend sample before aliquotting to specimen bottles.

8. Sediment sample locations are also determined using random number tables and are collected on the west side of the walkway. Sediment samples are collected using the soil corer auger. The auger is rotated 10 cm deep into the sediments. The sediment is then removed from the auger, using a plastic spoon if necessary, and placed in a decontaminated bucket. Multiple cores may need to be collected to provide sufficient volume for all sampling jars. Before aliquotting sediment to respective labeled jars, blend cores for an even mixture. Record number of cores collected at each station on the data sheet. Record location of any field duplicates on data sheet pertaining to that Test Cell (do not write Test Cell location on field duplicate jars).

Field Readings

Equipment Required

Surveyor 4 unit, connecting cable, Sonde calibration supplies

1. Retrieve Sonde from Porta-PSTA or Test Cell. Record time and date that Sonde was retrieved for field readings on the meter rotation log.
2. Calibrate Sonde following standard field procedures.
3. Field readings are taken on water sampling days. See table below for meter reading schedule. Field readings are also taken at both the Head Cell and Head Tank with each event.

Meter Reading Location Per Sampling Event

	Weekly Event	Monthly Event	Quarterly Event
Porta-PSTAs	Inflow Outflow	Inflow Center Outflow	Inflow Center Outflow
Test Cells	Inflow Outflow	Inflow 1/3 walkway 2/3 walkway Outflow	Inflow 1/3 walkway 2/3 walkway Outflow

4. Field readings are most accurately taken beginning at the outflow and proceeding 'upstream.' Place the meter into the water at approximately mid-depth at each station.
5. Allow meter to stabilize for approximately 1 minute before taking reading.
6. Record appropriate information from the Surveyor 4 unit onto data sheet and proceed to next station.
7. Upon completion of all field readings, replace Sonde back in its appropriate tank according to the meter rotation. Record time and date of deployment on the meter rotation log.

Quarterly Non-Reactive Phosphorus Testing of Periphyton and Sediments

Materials Required

Decontaminated buckets, 250 mL widemouth sediment packer jar, spoon, 10% HCl, Publix-grade DI water, aluminum foil.

To decontaminate buckets, rinse with dilute (10% HCl). Triple rinse buckets with Publix-grade de-ionized water. Allow to air dry and cover with aluminum foil.

Sediment Composite Sampling

1. Collect a sediment sample from designated sampling location of Porta-PSTA mesocosm (or Test Cell) and place in decontaminated bucket. Sampling locations for the Porta-PSTAs are determined from the random number tables that have already been generated. The 'X' value for the tank represents width (1 meter) and the 'Y' value for the tank is length (6 meters). The sample location on the random number table is written as an X/Y coordinate. The 0,0 coordinate is the southwest corner of the tank. The random number for the Test Cells sampling location represents location along the walkway, 50 denoting distal end of walkway. Periphyton samples are taken on the east side of the walkway, soil samples on the west side of the walkway. Note the sample time on the data sheet.
2. Collect approximately equivalent amounts of sediment from each of the Porta-PSTA mesocosms (or Test Cells, if applicable) comprising same treatment regime.
3. Thoroughly mix composite sample either by swirling or with a spoon if necessary.
4. Remove sample to be sent for testing from this mixed composite and place in labeled sediment packer jar. Note time collected on appropriate datasheet.
5. Ship to appropriate testing facility.

Periphyton Composite Sampling

1. Collect a small amount (up to 70 mL) of periphyton from Porta-PSTA mesocosm (or Test Cell). Note on datasheet pertaining to that mesocosm (Test Cell) if sampled periphyton is floating, benthic, or if both are sampled. Place periphyton specimen(s) in labeled sediment packer jar.
2. Note: Unlike periphyton sampling for monthly events, sampling periphyton for the composite NRP analysis is not limited to the area designated by the random number X/Y coordinate. Obtain a small sample of periphyton from any available location within the Porta-PSTAs for each treatment. Note on fieldsheet whether periphyton is benthic, floating, or epiphytic.
3. Collect periphyton from other mesocosms (or Test Cells, if applicable) within the same treatment protocol and add to the labeled jar. Note final time on appropriate datasheet.
4. Ship to appropriate facility.

Sonde Calibration

Equipment Required

Lab-grade deionized DI water; drinking water, pH standards 7 and 10, specific conductivity buffer standard, Hydrolab Surveyor 4 unit.

1. Retrieve Sonde from Test Cell or Porta-PSTA (if this Sonde is to be used for field measurements, mark Sonde ID number and time retrieved on Field Rotation Sheet). For all Sonde Meter Rotation and calibration events, note Sonde number and location from which Sonde was retrieved on Calibration datasheet.
2. Attach cable connecting Sonde to Surveyor 4; make sure all connections are tight.

Dissolved Oxygen Calibration

1. Unscrew weighted cap protecting sensors and replace with a MiniSonde cup, with lid in place, filled halfway with drinking water. The appropriate amount of water is such that, with the Sonde vertically oriented with the sensors pointing up, the water line should be just level with the O-ring that secures the Dissolved Oxygen (DO) membrane.
2. With the Sonde in the upright position, loosen cap completely. Check that no water droplets are present on the DO membrane; if droplets are present, blot gently with a clean cloth and replace cap loosely.
3. From the Surveyor 4 unit, record DO (in milligrams per liter [mg/L]), DO %, and temperature pre-calibration readings.
4. Select Sonde.
5. From the displayed menu, highlight DO % and press Select.
6. Verify, or enter the current value as 760 mm Hg and press Done.
7. The Surveyor 4 unit should beep and give the message, "Calibration Successful!" and prompt to press any key to return. The "Go Back" key must then next be depressed to return the field displaying all parameters being measured.
8. Re-read DO, %DO, and temperature, and note in post-calibration section of the Meter Calibration sheet.
9. Tighten cap on MiniSonde cup and remove cup from probe.

Specific Conductivity

1. Rinse probe with DI water and place in Specific Conductivity buffer. Record pre-calibration reading.
2. Select Sonde.
3. From the displayed menu, highlight SpCond mS/cm and press Select.
4. Verify, or enter calibration units to 1.00 and select Done.
5. The Surveyor 4 unit should beep and give the message, "Calibration Successful!" and prompt to press any key to return. The "Go Back" key must then next be depressed to return the field displaying all parameters being measured.

6. Re-read Specific Conductivity and note in post-calibration section of the Meter Calibration sheet along with temperature.

pH Calibration

1. Rinse MiniSonde probe with DI water and place in pH buffer standard 10; record pre-calibration reading.
2. Rinse probe with DI water and place in pH buffer standard 7; record pre-calibration reading.
3. Select Sonde.
4. From the displayed menu, highlight pH: Units and press Select.
5. Verify, or enter calibration units to 7.00 and select Done.
6. The Surveyor 4 unit should beep and give the message, "Calibration Successful!" and prompt to press any key to return. The "Go Back" key must then next be depressed to return the field displaying all parameters being measured.
7. Re-read pH and note in post-calibration section of the Meter Calibration sheet.
8. Rinse probe with DI water and place in pH buffer standard 10.
9. Select Sonde.
10. From the displayed menu, highlight pH: Units and press Select.
11. Verify, or enter calibration units to 10.00 and select Done.
12. The Surveyor 4 unit should beep and give the message, "Calibration Successful!" and prompt to press any key to return. The "Go Back" key must then next be depressed to return the field displaying all parameters being measured.
13. Re-read pH and temperature and note in post-calibration section of the Meter Calibration sheet along with time.
14. Rinse probe with DI water after all calibrations are complete.

Data Download, Meter Rotation, Programming and Maintenance

Equipment Required

Laptop computer, Surveyor 4 unit, connector cables, recharged batteries, allen wrench (9/64 in), paper towels, and any other material necessary to clean Sonde.

Head Cell Sonde with Internal Data Logger

1. Remove Sonde from Head Cell. Visually inspect Sonde, checking that the dissolved oxygen (DO) membrane is intact, the circulator free of algae and sensors clean; clean gently as necessary per instructions in Minisonde User's Manual. Loosen screws holding battery cap on either side of the Sonde with allen wrench.
2. Pull off battery cap and replace with charged batteries before attempting Data Download Calibration and Programming. Replace battery cap and screws.
3. Connect Sonde to laptop computer. From the desktop menu, select Shortcut to Series 4.
4. From the Menu bar, select the pull down menu Connect; choose Capture Data to a File.
5. Select *Unattended log file.*
6. Select the file to download from the scroll menu. Go to *Transfer file.*
7. Select *Do Transfer* (verify data are downloading to the appropriate file).
8. After transferring the data, select *Done* (there is a computer prompt when the file has finished transferring).
9. Open transferred file to verify all data downloaded properly.

Programming the Sonde with Surveyor 4

1. From the main menu in Surveyor 4 go to *Files* and select *Create.* Delete old files as necessary to create memory space.
2. When prompted for a name, enter the name of the new file.
3. Enter the start time in the format mm / dd / yy.
4. Enter the stop time in the format mm / dd / yy.
5. Enter Data to be sampled every 65 seconds.
6. Enter sensor cycle of 120.
7. Enter parameters to be added (temperature, TSS, pH, Conductivity, DO %, DO [mg/L]).
8. Enter audio *Off* (0 = off).
9. The surveyor will prompt for new file information.

Programming the Sonde with Laptop Computer

1. From the File menu go to *Create File*. Name the new file.
2. Add parameters (temperature, TSS, pH, Conductivity, DO %, DO [mg/L].)
3. Add sensors cycle of 120.
4. Sample time every 65 seconds.
5. Enter Audio *Off* (0 = off).
6. Enable the file.
7. Click done.

Downloading Data from Sonde with External Data Logger

1. Retrieve Sonde and data logger from Test Cell or Porta-PSTA; record time and date of retrieval on meter rotation fieldsheet.
2. Calibrate Sonde following standard field procedures.
3. Connect laptop to white data logger box using cable.
4. Open PC208w 3.0 program on the computer.
5. Select the menu item *Connect*.
6. Make sure the "Prompt for data file name" box is checked and select C*ollect All*.
7. Message box will appear with the path the file will be saved as. Select *Browse* and note saving location. Name the file in the format using Test Cell number or Porta-PSTA and download date (e.g. TC8W0309.dat or PP030900.dat).
8. Select the file name and path then press "*OK*." A status bar will appear displaying percent downloaded as the file is recorded.
9. When the status bar shows 100% collected, disconnect and open the file in Notepad. Verify data downloaded successfully. Record name of file along with time and date of download onto the meter rotation log.
10. Rotate Sonde into next Test Cell or Porta-PSTA. Sondes move in an ascending rotation in Test Cells (TC3, TC8 to TC13 then back to TC3). Keep Sonde with the proper data logger (i.e., Sonde 4 stays with data logger 1). Record the time and date of deployment as well as depth on the meter rotation fieldsheet. Sondes are deployed at mid-water depth in the Test Cell and Porta-PSTAs. Record depth from the surface of the sediment (bottom) to the location of the Sonde sensors.
11. Each of the three Porta-PSTA Sondes is assigned to a rotation of eight tanks. Make sure to keep the proper Sonde rotating in an ascending order though its assigned tanks. Also keep the proper sonde with the proper data cable (data cables are marked with zipties corresponding to the Sonde ID number). Record the time and date of deployment as well as the depth on the meter rotation log.

12. Temperature probes and the photosynthetically active radiation (PAR) meter are rotated on the same designated days with the Sondes at the Porta-PSTAs. These meters move though the 24 tanks in a descending rotation (PP24, PP23, etc.).

13. Record the time and date of retrieval, move the meter to the next tank in the rotation and record the time and date of deployment as well as the depth onto the meter rotation fieldsheet.

Percent Cover

Equipment Required

Fieldsheet for Percent Cover for Porta-PSTA or for Test Cells

Percent cover estimates are performed as part of the monthly sampling event.

1a. Each Porta-PSTA is effectively divided into thirds by two evenly spaced fiberglass cross pieces that support the tank. Percent cover is estimated in each third of the tank created by these divisions. The fieldsheet notes Porta-PSTA thirds as North, Center, and South.

1b. Each Test Cell is also effectively divided into thirds by the metal walkways. East of the eastern walkway is Zone A, between the two walkways is Zone B, and west of the west walkway is Zone C.

2. Characterize each third individually. Percent cover is estimated by visually assessing total surface area comprised of plant material compared with the entire third. Plant shading does not enter into the estimate, only that percent physically assumed by the plant.

3. Each third is assessed for Blue-Green Algal Mat, Green Algal Mat, Floating Aquatic Plants, Submerged Aquatic Plants, and Emergent Macrophytes. An "Other" column is provided for any additional observations.

4. Each assessment is keyed with the following values to represent percent coverage:

    1= <1%
    2= 1-5%
    3= 5-10%
    4= 10-25%
    5= 25-50%
    6= 50-75%
    7= 75-90%
    8= 90-95%
    9= 95-99%
    10= >99%

5. A list of plant types making up the percent cover is written in space provided on the fieldsheet corresponding to each percent cover assessment.

Snail Count

Equipment required

Ziploc bags, hand counter, permanent marker

1. For each Porta-PSTA, remove all snails seen.
2. Place snails in Ziploc bag labeled with Porta-PSTA number and date.
3. Record number and snail type on sheet of paper and in Field Notebook. Snails are typically of two types: *Helisoma*, with spiral round shell, and *Physa*, a smaller snail with conically shaped shell and spirals more noticeable toward tip of shell.
4. Double-bag snails particularly if a large amount have been collected.
5. Place snails in freezer until can be shipped for analysis.

APPENDIX D

Sampling Plans

Supplemental Technology Standard of Comparison (STSOC) Sampling Plan for the Periphyton Stormwater Treatment Area Research and Demonstration Project (C-E8624)

Supplemental Technology Standard of Comparison (STSOC) Sampling Plan for the Periphyton Stormwater Treatment Area Research and Demonstration Project (C-E8624)

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1.0 Introduction

1.1 Background

Best Management Practices (BMPs) and stormwater treatment areas (STAs) are providing preliminary treatment of agricultural runoff from the Everglades Agricultural Area. Additional Advanced Treatment Technologies (ATT) are currently under investigation to provide final treatment of this runoff before discharge to the remaining Everglades. To evaluate and compare results from these technologies in a scientifically valid manner, the South Florida Water Management District (District) along with PEER Consultants, P.C./Brown and Caldwell have developed a Supplemental Technology Standard of Comparison (STSOC) methodology.

The final STSOC methodology, as approved by the Everglades Technical Advisory Committee, consists of nine basic information requirements for each of ATT. As outlined below, five data requirements are considered primary, with the remaining four characterized as ancillary:

Primary:

- The level of phosphorus (P) concentration reduction achievable by the technology (from experimental data)
- The level of P load reduction (from model data)
- Compliance with Class III Water Quality Standards and compatibility of treated water with the natural population of aquatic flora and fauna in the Everglades

- Cost-effectiveness of the technology
- Implementation schedule

Ancillary:

- Feasibility and functionality of the scaled-up design and cost estimates
- Operational flexibility
- Sensitivity of the technology to fire, flood, drought and hurricane
- Level of effort required to manage, and the potential benefits to be derived from side streams generated by the treatment process

The ATT are currently under investigation by the District and other affected agencies [e.g. the Florida Department of Environmental Protection (FDEP)]. ATT project research teams are required to provide the District with background information concerning their technology, including mechanisms of P removal, discussions of various experimental trials, available flow and total phosphorus (TP) data and discussion of the treatment process.

1.2 STSOC and the PSTA Technology

The STSOC methodology was developed to guide performance documentation and the estimation of implementation costs of a broad group of potential P removal technologies. Some technologies are based on chemical and physical processes (e.g. chemical treatment / solids separation, low-intensity chemical dosing, etc.) while others rely on biological processes with no application of chemicals (e.g. submerged aquatic vegetation / limerock). Although the STSOC was written to ensure comparable information between all of these potential technologies, various STSOC requirements are more or less applicable to the two fundamentally different groups of technologies.

The periphyton-based stormwater treatment area (PSTA) concept is a "green technology," or one that relies upon a natural ecological system for P removal. Chemical treatment, solids management, and harvesting (periodic biomass removal) are not envisioned as components of this technology. As a result, STSOC issues pertaining to testing of waste side streams are not applicable to PSTA.

On behalf of the District, the CH2M HILL team has operated PSTAs at the Everglades Nutrient Removal (ENR) Project since February 1999. TP removals have been promising enough to continue to the STSOC stage of the project, using the selected Test Cell PSTAs as the basis of the analysis. . As an initial step in the STSOC process, this sampling plan details the data collection efforts for the evaluation of the PSTA concept, with specific focus on phosphorus reduction and compliance with representative Class III water quality standards listed in the STSOC guidelines.

2.0 Sampling Locations

Inflow and Outflow

PSTA research has been ongoing at three South Test Cells (STCs) within the ENR Project for two years. Data verification and STSOC monitoring will be performed on two of these cells, Test Cells 8 and 13. These Test Cells represent the largest scale PSTAs tested to date. Water

quality monitoring locations will include the STC Head Cell and the outflow points from the two individual cells.

Side Streams and Seepage

The STSOC requires that side streams and seepage (if >20% of the inflow) be sampled. Because the PSTA technology is a green technology, no residual waste streams are produced. In addition, no leakage from the test cells occurs because each is lined. Therefore, no sampling of side streams or seepage will be performed as part of the PSTA STSOC evaluation.

3.0 Data Collection

3.1 Flow Measurement

Inflow measurements are calculated according to District data and knowledge of the inflow orifice size. Inflows are relatively constant to the test cells because they are derived from a Head Cell that feeds all of the test cells at each location. The water level in the Head Cell is maintained within a relatively small range by an automatic pumping system. Water surface elevation in the Head Cell is continuously recorded (every 15 minutes) by the District. Those Head Cell water level measurements and inflow orifice information will be used for inflow estimation to the PSTA Test Cells. The District is currently providing daily average inflows based on their stage records from the Head Cell.

Inflow rates are calculated by use of calibration equations prepared by the District for each of several possible inflow pipe orifices. The inflow equation for the PSTA Test Cells with the 0.75-inch orifice plates is:

$$Q = 0.004561*H - 0.07561 \qquad \text{Equation 3.1}$$

Where: Q = flow, cfs

H = head cell stage, feet

Daily outflow from the PSTA Test Cells will be calculated for the STSOC sampling period. Remote Data Systems (RDS) water level recorders (RDS WL-40) will be installed at the outflow weir box for each of the two PSTA Test Cells being evaluated. These RDS units will record the water stage in the weir box every hour (24 records per day). These values will be used to estimate outflow from the individual PSTA Test Cells on an hourly basis using the equation for flow over a 90-degree V-notch weir:

$$Q = 2.50*H^{5/2} \qquad \text{Equation 3.2}$$

Where: Q = flow, cfs

H = water head over the base of the V-notch, feet

Data in cfs will be converted to m^3/d using the relationship:

$$Q\ (m^3/d) = 2446.6*Q\ (cfs) \qquad \text{Equation 3.3}$$

3.2 Water Quality Parameters and Sampling Methods

Sampling methodology will be conducted using methods identified in CH2M Hill's FDEP-approved Comprehensive Quality Assurance Plan (CompQAP) No. 910036G and clarified in the PSTA Quality Assurance Plan (QAPP) approved by the District. Phosphorus analyses will continue to be conducted by the University of Florida Institute of Food and Agricultural Sciences (IFAS) under their CompQAP No. 910051. Environmental Conservation Laboratories (ENCO) will analyze the total organic carbon (TOC) samples per their CompQAP No. 960038. PPB Environmental Laboratory (PPB) will analyze the remaining parameters under their CompQAP No. 870017G. STSOC water quality parameters and the sampling frequencies are summarized in Exhibit 1.

EXHIBIT 1

STSOC Water Quality Parameters and Proposed Sampling Frequencies

PSTA Research and Demonstration Project

Parameters	Units	Analytical Method	Method Detection Limit	Inflow and Outflow Sampling Frequency	
				STSOC Recommendations	Proposed PSTA Plan
GROUP A					
TP	mg/L as P	EPA 365.4	0.001	24 hr composite	24 hr composite
GROUP B					
TDP	mg/L as P	EPA 365.1	0.001	24 hr composite	Twice per week grab[1]
DRP	mg/L as P	EPA 365.1	0.0004	24 hr composite	Twice per week grab[1]
Turbidity	NTU	EPA 180.1	0.1	NS	Twice per week grab[1]
Color	CU	EPA 110.2	5	NS	Twice per week grab[1]
GROUP C					
TSS	mg/L	EPA 160.2	2	Every 3rd Composite	Every 3rd Composite
TOC	mg/L	EPA 415.1	1	Every 3rd Composite	Every 3rd Composite
Alkalinity	mg/L as $CaCO_3$	EPA 310.1	1	Every 3rd Composite	Every 3rd Composite
TDS	mg/L	EPA 160.1	3	Every 3rd Composite	Every 3rd Composite
Sulfate	mg/L	EPA 375.4	1.5	Every 3rd Composite	Every 3rd Composite
Chloride	mg/L	EPA 325.2	0.2	Every 3rd Composite	Every 3rd Composite
TKN	mg/L as N	EPA 351.2	0.1	Every 3rd Composite	Every 3rd Composite
Nitrate/Nitrite[2]	mg/L as N	EPA 353.2	0.004	Every 3rd Composite	Every 3rd Composite
NH_3	mg/L as N	EPA 350.1	0.003	Every 3rd Composite	Every 3rd Composite
GROUP D					
Dissolved Al	µg/L	EPA 202.2/200.7[3]	4.5	5 times	5 times
Dissolved Fe	µg/L	EPA 200.7	4	5 times	5 times
Dissolved Ca	mg/L	EPA 200.7/60.0	0.013	5 times	5 times
Dissolved Mg	mg/L	EPA 200.7/60.0	0.01	5 times	5 times
Dissolved K	mg/L	EPA 258.1	0.04	5 times	5 times
Dissolved Na	mg/L	EPA 200.7	0.15	5 times	5 times
Reactive Silica	mg/L	EPA 370.1	0.2	5 times	5 times
GROUP E					**Inflow/Outflow**
Conductivity	µs/cm	NA	NA	NS	Twice per week
DO	mg/L	NA	NA	NS	Twice per week
pH	Units	NA	NA	NS	Twice per week
Temperature	°C	NA	NA	NS	Twice per week

NS = Not specified in the STSOC guidelines

NA = Not applicable; field readings will be collected in situ.

[1] Twice per week grab collected to meet FDEP-required filtering requirements and short holding times (48-hours).

[2] To be consistent with current monitoring at the PSTA test cells, nitrate/nitrite will be reported instead of each component separately.

[3] Aluminum samples below approximately 100 µg/L are analyzed by EPA 202.2 (GFAA); samples above approximately 100 µg/L are analyzed by EPA 200.7 (ICP).

Composite samples will be collected three times per week using automated ISCO samplers. Each 24-hour composite will consist of discrete grabs collected every 2 hours in 120 mL bottles. Grabs from each 24-hour period (12 samples) will then be composited prior to the filling of individual sample containers.

Project data for the study period (February 1999 to present) indicate that concentrations of dissolved reactive phosphorus (DRP) at the PSTA Test Cells are consistently below the method detection limit, with averages below 10 µg/L (*Phase 1 Summary Report*, CH2M HILL, August 2000). In accordance with FDEP-approved procedures and holding times, DRP samples must be filtered and shipped immediately after collection for analysis within 48-hours. For these reasons, this parameter is included in Group B. Two weekly grab samples will be collected at the three monitoring stations over the STSOC study period for DRP analysis. These same grab samples will also be analyzed for TDP.

3.3 Monitoring Schedule

The STSOC specifications call for a testing duration of at least 5 times the average hydraulic retention time (HRT). Based on a planned hydraulic loading rate of 5 cm per day and a 30 cm water depth, the nominal HRT will be 6 days for the testing period. The proposed STSOC sampling duration will be 5 weeks.

ISCO samplers will be programmed to collect three 24-hour composite samples per week for periods ending Monday, Tuesday and Thursday as outlined below.

- **Composite 1:** This composite will be for the nominal period of Sunday at 10 AM to Monday at 10 AM and will be analyzed for Group A.
- **Composite 2:** This composite will be for the nominal period of Monday at –10 AM to Tuesday at 10 AM and will be analyzed for Groups A, B, C and D. Because of short holding times (48-hours) and filtration requirements, grab samples will be collected for TDP, DRP, color and turbidity.
- **Composite 3:** This composite will be for the nominal period of Wednesday at 10 AM to Thursday at 10 AM and will be analyzed for Groups A and B.

Composite samples will be retrieved and processed on Tuesdays and Thursdays. Field measurements (Group E) will be collected in situ twice per week at the three monitoring locations. Under the PSTA monitoring program, continuous field measurements for Group E parameters have been recorded at the three STSOC monitoring locations on a rotating basis since February 1999.

Samples will be transferred to pre-cleaned and properly labeled sample containers following collection. TDP and DRP samples will be filtered using a 0.45 µm filter. Sample preservatives may be either included in the sample container by the laboratory or added to the sample immediately after collection. All samples will be placed in coolers with ice immediately following collection.

STSOC water quality sampling will be conducted over a 5-week period. Exhibit 2 summarizes the proposed number of samples to be collected over the study period.

EXHIBIT 2

Proposed Number of STSOC Water Quality Samples by Parameter Group

PSTA Research and Demonstration Project

Parameter Group	STSOC Suggested	Proposed PSTA Sample Numbers				
		Total Per Station	No. of Stations	Total Field Samples	QA/QC Samples	Total
A	40[1]	15	3	45	8	53
B	40[1]	10	3	30	5	35
C	13	5	3	15	3	18
D	5	5	3	15	3	18
E	Not specified	10	3	30	0	30

[1] Includes TP, TDP and DRP

3.4 Toxicity Testing

The STSOC guidelines call for assessment of "marsh readiness" through performance of algal growth potential (AGP), and chronic toxicity tests. Typically, AGP tests are run with *Selanastrum capricornatum*. The chronic toxicity tests normally are run with *Ceriodaphnia dubia* and *Cyprinella leedsi*. For the PSTA STSOC evaluation, the Florida Department of Environmental Protection (FDEP) will perform these tests with a combined inflow sample from the head cell, and the individual outflow samples from Test Cells 13 and 8. These tests will be run on single grab samples collected from the above locations as directed by FDEP during the week of March 5, 2001. Additional samples will be collected to support sample renewals if so directed by FDEP. Test results will be evaluated in conjunction with the analytical data from the corresponding week. This testing plan was provided following FDEP discussions in Tallahassee, and selection of this level of toxicity assessment as appropriate for the PSTA STSOC analysis.

4.0 Quality Assurance

4.1 Quality Control Measures

All testing and sample handling will be carried out as outlined in the QAPP for execution of field activities, proper completion of chain-of-custody forms, sample preservation and proper handling of samples. Laboratory personnel will follow procedures outlined in the laboratory's CompQAP for sample kit preparation, tracking, analysis of samples and data validation.

Field meters will be calibrated by the field team in accordance with the manufacturer's recommendations. Calibration results will be recorded and maintained with the field data sheets for each event.

Field Quality Assurance / Quality Control (QA / QC) samples will be collected at the following rate:

- Duplicates (10 percent of total samples)
- Equipment Blanks (5 percent of total samples)

Samples will be shipped by commercial overnight delivery service to the appropriate laboratory(s) on the day of collection and processing.

4.2 Field Records

A field notebook will be maintained to record field observations. Associated field sheets recording times of sample collection, weather conditions and field parameters will be maintained in the field notebook. Copies of chain of custody forms will be maintained with the field records.

PSTA STSOC Sampling Plan Approvals

Approved for Florida Department of Environmental Protection

Name/Title: Tampa Deldari, PROJECT MANAGER Date: 2/13/01

Approved for South Florida Water Management District

Name/Title: Lai Wan, Project Manager Date: 2·26·01

Approved for CH2M HILL

Name/Title: Steven W. Song, Project Manager Date: 2/26/01

Porta-PSTA Mass Balance (Destructive) Sampling Plan

Porta-PSTA Mass Balance (Destructive) Sampling Plan

Periphyton-Based Stormwater Treatment Area Research and Demonstration Project

Prepared for

Florida Department of Environmental Protection

February 2001

Contents

Porta-PSTA Mass Balance (Destructive) Sampling Plan Approvals

Approved for Florida Department of Environmental Protection

Name/Title: [signature], PROJECT MANAGER Date: 2/8/01

Approved for South Florida Water Management District

Name/Title: [signature], Project Manager Date: 2-12-01

Approved for CH2M HILL

Name/ Title: Steven W. Long, Project Manager Date: 2/9/01

SECTION 1

Introduction

SECTION 1

Introduction

1.1 Background

The South Florida Water Management District (District) is conducting research focused on determining the effectiveness and design criteria of potential advanced treatment technologies to support reduction of phosphorus loads in surface waters entering the remaining Everglades. Periphyton-based stormwater treatment areas (PSTAs) are one of the advanced treatment technologies being researched by the District for potential application downstream of the macrophyte-based stormwater treatment areas (STAs).

Twenty-four Portable PSTA (Porta-PSTA) mesocosms have been operated for approximately 18-months as part of the PSTA Research and Demonstration Project sponsored by the District (Contract C-E8624). Monitoring of the Porta-PSTAs for the authorized period was completed in early October 2000. These mesocosms are located within the District's Everglades Nutrient Removal (ENR) project, as depicted in Exhibit 1-1. The Porta-PSTAs represent the smallest scale of PSTA research; larger mesocosms (PSTA Test Cells) will continue to be monitored under the District contract through March 2001, and studies of field scale pilot PSTAs are currently under start-up mode.

One aspect of the Porta-PSTA research was the documentation of input/output mass balances for water and total phosphorus (TP). Recommendations from the PSTA Scientific Review Panel (SRP) and other outside interested parties during the September 9-10, 2000, and the January 13-14, 2001, SRP workshops included performance of "destructive sampling" of a subset of the Porta-PSTAs to support the mass balance analyses.

1.2 Project Objectives

This study has two primary objectives:

1. To quantify the ending mass of TP in the various potential storage media within a subset of the Porta-PSTA mesocosms

2. To support mass balance assessments previously based solely on input and output information.

This sampling plan outlines the activities that will be conducted by the CH2M HILL team to achieve these study objectives. Results of these analyses will be integrated with the other analyses the consulting team is already engaged with on behalf of the District under the referenced contract.

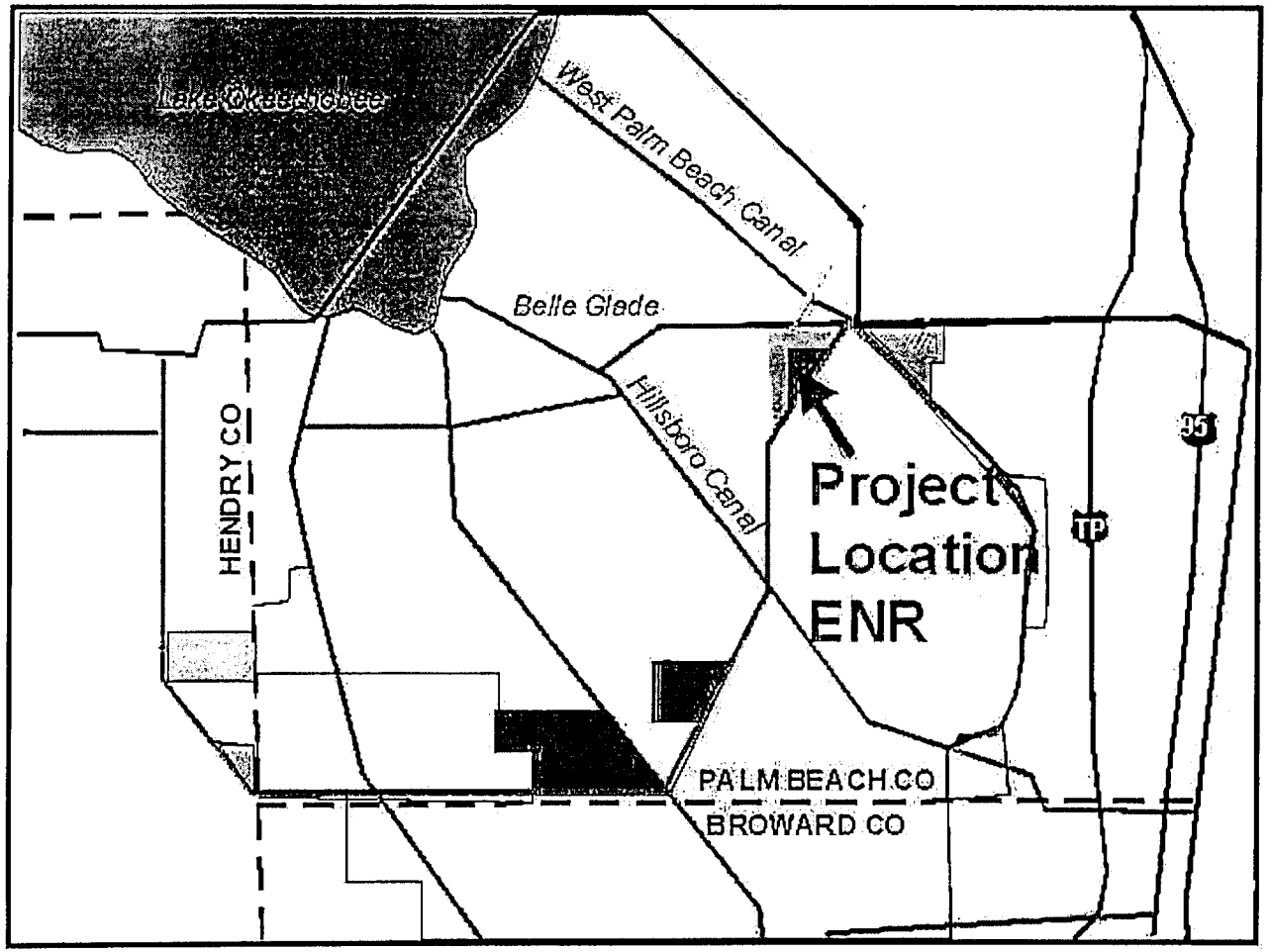

Exhibit 1-1
Site Location

SECTION 2

Field Sampling and Analytical Procedures

SECTION 2

Field Sampling and Analytical Procedures

2.1 Porta-PSTA Mesocosms

The Porta-PSTA tanks are 1x6 m in size (6 m^2 surface area) and 1 m deep, and are constructed of fiberglass. For this study, the following 10 Porta-PSTAs will be destructively sampled:

- Peat Treatment PP-3 (Tanks 12, 14, 17)
- Shellrock Treatment PP-4 (Tanks 3, 5, 10)
- Sand Control Treatments PP-7 and PP-17 (Tanks 19, 20)
- No substrate Control Treatments PP-18 and PP-19 (Tanks 21, 22)

2.2 Sampling Methods and Analytical Parameters

Sampling methods will be essentially the same as those used throughout the ongoing PSTA study and previously approved by the District. The field team will separately sample each of the following compartments in the 10 Porta-PSTAs:

- **Floating periphyton mat and Metaphyton:** All floating mat and metaphyton will be removed from the 10 Porta-PSTA tanks with an aquarium net or by hand and placed into a bucket to be homogenized with a stainless steel paddle or spoon. The total volume of slurry will be estimated and then subsampled for TP, total inorganic phosphorus (TiP), calcium (Ca), dry weight (DW), and ash-free dry weight (AFDW) analyses.
- **Wall periphyton:** The Porta-PSTA tank walls will be scraped and the accumulated periphyton will be placed in a bucket for estimation of the wet volume. Following mixing, this material will be subsampled for TP, total inorganic phosphorus (TiP), Ca, DW, and AFDW analyses.
- **Benthic periphyton:** The benthic periphyton will be removed from each of the 10 Porta-PSTA tanks by hand to the extent possible and placed in a bucket for estimation of wet volume. Following homogenization, this material will be subsampled for TP, TiP, Ca, DW and AFDW analyses.
- **End Wall periphyton:** A sample of periphyton from both inflow and outflow endwalls of the tanks will be removed by scraping, the volume estimated and sampled for taxonomic analysis only.
- **Plant Harvesting:** All aboveground macrophytes (including submerged aquatic vegetation and emergent plants) from the 10 Porta-PSTA tanks will be removed in their entirety and cut to represent an above ground portion and a below ground portion. Each collective portion will be weighed wet. Subsamples from each portion of each tank will be collected for analysis of TP, TiP, Ca, DW and AFDW.

- **Grazers (snails, fish, etc.):** All grazers observed in each of the 10 Porta-PSTA tanks will be identified and collected as a single sample for analysis from each tank. The sample will be analyzed for TP, TiP, Ca, DW and AFDW.
- **Sediments:** Soils will be collected at two depths (0-10 cm and 10-20 cm increments) using a small shovel and composited from a minimum of 10 locations within each of the 10 Porta-PSTA tanks. These composite samples will be subsampled for estimates of bulk density, percent solids, TP, TiP and Ca.
- **Horizon markers:** Horizon markers were placed in each of the substrate treatment Porta-PSTAs to quantify soil accumulation rate. Soils will be cored at each of the horizon markers and the soil layer over the horizon marker will be measured and collected for analysis of bulk density, percent solids, TP, TiP and Ca.

Except for soils, each compartment will be completely sampled and homogenized, measured (wet weight or volume), and subsampled for gravimetric and chemical analyses. Two subsamples will be analyzed for each of the three periphyton components (excludes endwall periphyton), for the macrophytes, and for each of the soil compartments. Sediment sample above the horizon marker and grazers will be entirely consumed in a single sample for analysis. Soil samples will be composited from a minimum of ten locations in each tank, and the composited samples will be subsampled for analyses. A summary of the analytical parameters by matrix is provided in Exhibit 2-1.

EXHIBIT 2-1
Analytical Parameters for the Porta-PSTA Destructive Sampling
PSTA Research and Demonstration Project

Media	Parameters and Number of Samples									
	No. of Samples per Cell	No. of Cells	TP	TiP	Tax	Ca	DW	AFDW	Wet Bulk Density	% Solids
Floating Mat/Metaphyton	2	10	20	10	--	20	20	20	--	--
Consumers (snails, fish, etc.)	1	10	10	10	--	10	10	10	--	--
Wall 'Mat'	2	10	20	10	--	20	20	20	--	--
Benthic Mat	2	10	20	10	--	20	20	20	--	--
Endwall Mat	2	10	--	--	20	--	--	--	--	--
Macrophytes- above Ground	2	8	16	8	--	16	16	16	--	--
Macrophytes- below Ground	2	8	16	8	--	16	16	16	--	--
Sediments (0-10 cm)	2	8	16	8	--	16	--	--	16	16
(10-20 cm)	2	8	16	8	--	16	--	--	16	16
(horizon marker)	1	8	8	8	--	8	--	--	8	8
Collected Samples			142	80	20	142	102	102	40	40
QA/QC Samples			21	12	--	21	10	10	4	4
Total Samples			**163**	**92**	**20**	**163**	**112**	**112**	**44**	**44**

2.3 Field and Analytical Team Members

CH2M HILL personnel will collect the Porta-PSTA destructive samples in accordance with CH2M HILL's Comprehensive Quality Assurance Plan (CompQAP) No. 910036G. In addition, WSI personnel will participate in sample collection in accordance their CompQAP No. (21003). Analytical work will be conducted by the following laboratories:

- University of Florida Institute of Food and Agricultural Sciences (IFAS) (CompQAP No. 910051)
- PPB Laboratories (CompQAP No. 870017-19)
- Law Engineering (CompQAP No. 950024).
- WAR (CompQAP No. 900211-15)

A detailed breakdown of parameters by laboratory and proposed analytical methods are provided in Exhibit 2-2. These same methods are being applied by these same laboratories for the District's overall PSTA Research and Demonstration Project.

EXHIBIT 2-2
Analytical Laboratories Methods for the Porta-PSTA Destructive Sampling
PSTA Research and Demonstration Project

	Analytical Laboratories and Methods			
	IFAS	PPB		Law Engineering
Media	TP	Ca	Biomass [3]	Wet Bulk Density and % Solids
Periphyton [1]	Kuo (1996) and Anderson (1976)	EPA 6010	SM 10200I	NA
Consumers [2]	Kuo (1996) and Anderson (1976)	EPA 6010	SM 10200I	NA
Emergent/Submerged Plants	Kuo (1996) and Anderson (1976)	EPA 6010	SM 10200I	NA
Sediments	Kuo (1996) and Anderson (1976)	EPA 6010	NA	ASTM D2937

1 Includes floating mat, metaphyton, wall and benthic periphyton
2 Includes snail, fish or other grazer species
3 Biomass comprises the reporting of dry weight and ash free dry weight.
NA = Not analyzed

2.4 Field QC Checks

Field QC samples will be collected during the program to provide data for the evaluation of QC in regard to sample collection and handling. Under this program, the following field control samples will be collected: field duplicates and equipment blanks. A description of each field QC sample is provided in Exhibit 2-3 along with applicable matrices and collection frequency.

EXHIBIT 2-3
Summary of Field QC Checks
PSTA Research and Demonstration Project

Type	Collection	Definition	Frequency
Equipment Blank	Sediment and Periphyton Samples	An equipment blank is designed to detect contamination of environmental samples caused by contamination of sampling equipment. An equipment blank is analyte-free water that is poured into the sampling device, transferred to a sample bottle, and transported to a laboratory for analysis. When no sampling equipment is required for sample collection, analyte-free water will be poured directly into the sample container.	Equipment blank(s) shall be taken at a rate of 5% of total number of samples collected. This blank shall be analyzed for all laboratory analyses requested for environ–mental samples collected at the site on that day, except for grazers and plant samples.
Field Duplicate	Sediment and Periphyton Samples	A field duplicate is a sample collected, in addition to the native sample, at the same sampling location and at the same sampling event. The field duplicate is designed to check repeatability or precision of data in the laboratory.	Ten percent of all periphyton and sediment samples shall be field duplicates. Both duplicates (e.g., the sample and the duplicate) shall be analyzed for the same parameters in the laboratory. The analytical laboratories will be responsible for preparing duplicate samples for grazers and plant samples following sample homogenization, if sufficient sample volume is available.

SECTION 3

Quality Control

SECTION 3

Quality Control

3.1 QA and QC

QA is defined as those established protocols that provide adequate confidence that field activities are planned and performed in accordance with accepted standards and practices to ensure the resulting data are valid. QC is an integral part of the overall QA function and is comprised of all actions necessary to control and verify that project activities and resulting data meet established requirements.

To ensure that an adequate level of data quality is achieved, the following activities will be conducted:

- Field operations will be conducted in accordance with the Porta-PSTA Destructive Sampling Plan
- Prior to implementation of the field activities, project staff will be provided with appropriate training to ensure familiarity with the Porta-PSTA Destructive Sampling Plan
- QC samples will be used to monitor the quality of field and laboratory data

3.2 Sample Management

3.2.1 Sample Labels

Sample labels will be waterproof and will be placed on the outside of the sample container. Each label will provide the following information:

- Project name
- Site identification
- Analytical method
- Preservation (if appropriate)
- Date and time of sample collection
- Analytical laboratory
- Collector's initials

Sample containers will be grouped in the coolers by mesocosm; the cap of each sample container will be marked with the station name and depth to facilitate sample bottle identification.

3.2.2 Sample Custody

Chain-of-custody (COC) protocols include COC activities in the field, as well as shipping the samples to the offsite laboratory. COC forms will be completed and sent with samples shipped to the analytical laboratory in the shipping container (cooler) with the corres-

ponding samples. Legal field custody begins when the clean sample containers are obtained from the laboratory and ends when those samples are relinquished to the laboratory for testing.

When custody is transferred to a bonded courier for next-day delivery, the COC form is signed and dated by the individual who relinquishes custody. The COC is placed in a plastic bag and taped to the inside lid of the cooler. The shipping document from the bonded courier is used in lieu of a signature on the COC while the courier holds custody. Custody seals are used on the shipping containers when samples are shipped to the laboratory, to ensure no sample tampering occurred during transportation.

3.2.3 Sample Handling

Samples will be transferred to pre-cleaned and properly labeled sample containers following collection. Sample preservatives may be either included in the sample container by the laboratory or added to the sample immediately after collection. All samples will be placed in coolers with ice immediately following collection.

Samples will be shipped to a laboratory using the procedures provided below:

1. A large heavy-duty garbage bag will be placed in the cooler. Sample bottles will be placed inside a garbage bag in the cooler, and packing material will be inserted, where appropriate, to ensure that the bottles will not move during shipment. Remaining space in the cooler will be filled with fresh ice, and the garbage bag will be closed and secured using strapping tape.
2. Completed and signed COC will be placed in a ziploc, sealed and taped to the inside lid of the appropriate cooler. Strapping tape will be wrapped all around the cooler in two locations to securely close cooler lids. A shipping label will be placed on the top or front of the cooler and covered with clear plastic tape.

Upon receipt, the laboratory custody personnel will conduct the following checks:

1. Coolers will be checked for damage or leakage.
2. Sample containers will be compared to the information on the COC to ensure that all containers are accounted for, and will be inspected for breakage. If sample containers are missing or broken, the laboratory will notify the field team leader immediately.
3. The date and time of sample receipt by the laboratory will be noted on the COC. The laboratory person who receives and inspects the sample kits will also sign the COC acknowledging receipt.

Following the signing of the COC, the laboratory accepts responsibility for proper storage, tracking, analysis and disposal of the samples.

3.3 Field Recordkeeping

Field personnel will maintain records of field operations, sampling, and measurement in bound notebooks. Entries in the notebook will be made with indelible ink. Documentation in the field notebooks will include the following:

- Project title
- Location
- Date and time of sampling collection
- Type of sampling
- Names of field crew
- Weather conditions during field activity
- Depth of sample
- Sample description
- Signature of primary notetaker

If entries in the field notebooks need to be corrected or changed, corrections will be made by crossing out mistakes with a single line, writing the corrections and initialing and dating the entry. The use of correction fluid is not permitted. In addition to the field notebooks, COC forms will also be used to document field efforts.

3.4 Data Management

Field notes and laboratory reports will be reviewed as part of the internal QC process. The following activities will occur during the review of the data collected during the destructive sampling:

- Confirm correct information shown on the chain-of-custody forms
- Review results of equipment blanks. If target compounds appear in the blanks, discuss
- Sampling techniques with the field team leader.
- Verify that holding times were met for all parameters
- Verify that appropriate analytical methods were used for all parameters
- Compare results with previous data to identify possible outliers, if available.
- Analytical and field results will be incorporated in the PSTA database. The accuracy of manual data entry and file importation will be verified.

SECTION 4

Data Reporting

SECTION 4

Data Reporting

Field and laboratory data will be summarized in a brief technical memorandum and concurrently distributed to FDEP and the District for technical review. The technical memorandum will provide, as appendices, raw data from the destructive sampling and an analysis of the total mass of TP, Ca, and carbon (organic matter) present in these tanks at the time of the sampling. These data will be reported for each of the sampled matrices and for the tanks as a whole. Data from replicate tanks will be compared as appropriate. Data will be analyzed in a fashion to allow for easy incorporation in the PSTA Research and Demonstration Project Phase 2 Summary Report, which will be prepared by CH2M HILL under the existing District contract.

In accordance with the requirements of the FDEP contract, this final deliverable will include the acknowledgement that the project "…and the preparation of this technical memorandum was funded in part by a Section 106 Clean Water Act grant from the U.S. Environmental Protection Agency (USEPA) through a contract with the Stormwater/Nonpoint Source Management Section of the Florida Department of Environmental Protection. The total cost of the project was $49,978.84, of which 100% was provided by the USEPA."